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PART II.

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EXPLORATIONS AND SURVEYS FOR A RAILROAD ROUTE FROM THE MISSISSIPPI RIVER TO THE PACIFIC OCEAN.
WAR DEPARTMENT.

ROUTES IN CALIFORNIA AND OREGON EXPLORED BY LIEUT. R. S. WILLIAMSON, CORPS OF TOPOGRAPHICAL ENGINEERS, AND LIEUT. HENRY L. ABBOT, CORPS OF TOPOGRAPHICAL ENGINEERS, IN 1855.

GEOLOGICAL REPORT.

WASHINGTON, D. C.
1856.

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BY J. S. NEWBERRY, M. D.,
GEOLOGIST AND BOTANIST OF THE EXPEDITION.

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CONDUCTED UNDER THE DIRECTION OF PROFESSOR E. N. HORSFORD.

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No. 1.

REPORT UPON THE GEOLOGY OF THE ROUTE.

BY J. S. NEWBERRY, M.D.
GEOLOGIST OF THE EXPEDITION.

CHAPTER I.

GEOLOGY OF THE VICINITY OF SAN FRANCISCO.

GENERAL FEATURES GIVEN BY PARALLEL AXES OF ELEVATION.—BAY OF SAN FRANCISCO OCCUPYING A SYNCLINAL TROUGH.—GENERAL TREND OF RANGES NORTHWEST AND SOUTHEAST.—COAST MOUNTAINS GIVE OUTLINE AND DIRECTION TO THE COAST.—LOCAL GEOLOGY.—SAN FRANCISCO RANGE.—GOLDEN GATE CUT THROUGH IT.—CENTRE, TRAP AND SERPENTINE.—PHYSICAL CHARACTERS OF THE SERPENTINE.—CHEMICAL ANALYSIS.—SERPENTINE, SANDSTONES, AND SHALES.—FITNESS OF THE SANDSTONE FOR ARCHITECTURAL PURPOSES.—IT CONTAINS FEW FOSSILS.—SCUTELLA INTERLINEATA.—JASPER.—DRIFTING SAND.—ALLUVIAL DEPOSITS.—GEOLOGY OF SAN PABLO BAY.—SANDSTONES AND SHALES OF THE SAN FRANCISCO GROUP.—SANDSTONES FOSSILIFEROUS.—PECTEN BED.—OTHER FOSSIL SHELLS.—TUFAS AND MARLS FORMING SERIES OF GREAT THICKNESS.—UPPER MEMBERS VERY MODERN, AND OF VOLCANIC ORIGIN.—BEDS OF RECENT OYSTER SHELLS.—CHANGES OF LEVEL.—PROBABLE COMMUNICATION FORMERLY EXISTING BETWEEN SAN PABLO BAY AND THE OCEAN.—STRAITS OF CARQUINES.—SANDSTONES AND SHALES.—LAMINÆ OF GYPSUM.—BENICIA.—SANDSTONES EQUIVALENTS OF THOSE OF SAN FRANCISCO.—RIDGE OF JASPER NORTHWEST OF BENICIA.—WARM SULPHUR SPRING.—SOIL.—GEOLOGY OF MOUNT DIABLO.—GOLD.—SUISUN BAY.—CALCAREOUS TUFA.—TRAP HILLS.—SAN FRANCISCO SANDSTONE FORMING HILLS NEAR VACAVILLE.

GENERAL FEATURES.

THE configuration of the country in the vicinity of San Francisco has been given by two principal, and nearly parallel lines of upheaval, one passing between the city and the Pacific, forming the barrier through which the Golden Gate has been cut, the other that of the Contra Costa mountains. These, with several subordinate axes, which exert a local influence on its structure, properly belong to the compound chain of the coast mountains, have the same geological structure, and are doubtless of the same age. They are composed of serpentine or trap at centre, flanked by heavy beds of shales and sandstones of the tertiary period.

The general trend of these ranges is northwest and southeast, and they belong to the same system of elevation with that which has given the general outline and direction of the coast from Cape St. Lucas to Cape Mendocino. The islands which are scattered along the coast of California within the limits specified apparently lie in the lines of some of the axes of this system.

The Bay of San Francisco and the valley south of it occupy the synclinal trough which lies between the two axes I have mentioned. This depression, geologically considered, forms but a single area, which should be viewed as a whole, and which may properly be termed the valley of San Francisco bay. Of this area the valley of San Juan forms the southern, San Francisco

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bay the middle, and the western half of San Pablo bay and Sonoma valley the northern portion. Towards its southern extremity it is enclosed between the San Francisco or Coast Range and the Diablo mountains, with which the Contra Costa range here unites. Near its northern end the Contra Costa range may be said to terminate, permitting San Pablo bay to stretch eastward to the base of the Diablo mountains, thus adding the eastern half of this bay and Napa valley to its area.

The subordinate axes which traverse this valley have produced the island of Yerba Buena, the east and west shores of the straits connecting San Francisco and San Pablo bays, Point San Pedro, &c. Through the most westerly of these axes the Golden Gate is opened as a narrow strait, of great depth, and bounded by rocky, and in some places, precipitous walls. Through the most easterly the straits of Carquines pass, presenting the same general characters.

LOCAL GEOLOGY.

San Francisco range.—This range, in the vicinity of the city of San Francisco, forms low mountains or hills, none of which exceed 2,000 feet in height. They are composed of shales, sandstones, serpentine, and trap.

Trap.—This forms the lowest and central portion of the range, where it is cut by the Golden Gate, and is only exposed low down in the cliff which forms the north wall of this strait.

A few miles further north, in the same range, trap has been poured out in abundance, but it has apparently not burst through the overlying strata anywhere in the vicinity of San Francisco. The trap of the Golden Gate is dark brown in color, and more compact than that which has reached the surface in the vicinity of Petaluma.

Serpentine.—Overlying the trap on the north side of the gate, and on the south side forming the axis and nucleus of the chain, are heavy beds or masses of serpentine. Here, as wherever found in the vicinity of San Francisco, it is grayish green in color, and varies considerably in hardness and texture; the weathered portion being rendered friable by numerous joints, of which the surfaces are more or less covered with a white, probably magnesian, stain. At Fort Point, the best exposure of this rock which I saw, some portions of it are very compact and homogeneous, while others are somewhat foliated. The position which it occupies, and the relations which it sustains to the accompanying strata, seemed to me to indicate that it is an erupted rock. It forms the centre of the ridge, bearing on either side the inclined and convoluted strata of sandstones and shales, which cover and embrace it.

It is, perhaps, possible that it is a metamorphosed form of one of the group of stratified deposits with which it is associated, but the sandstones and shales, fossiliferous or barren, which, with trap, serpentine, and granite, go to make up the mass of the Coast Mountains, are scarcely capable of assuming this form under any phase of metamorphic action with which we are familiar; nor is there a dolomite or other magnesian rock on the western coast, which might be supposed to exhibit the unchanged state of the serpentine.

My own observations would therefore lead me to consider it an intruded rock, whatever inferences as to the origin of serpentine might be drawn from other localities, till new facts shall be brought to light, which will offer a more plausible explanation of the phenomena.

As the origin and composition of serpentines have recently afforded interesting subjects of inquiry to geologists and chemists, and as it has been suggested that the serpentine of California, as has been proved of some of the eastern (so called) serpentines, was, perhaps, not a magnesian

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rock, I submitted a specimen from the vicinity of San Francisco to Dr. J. D. Easter, for analysis, and upon it he has made the following report:

Massive serpentine from California.

The specimen was somewhat decomposed, of a mottled grayish-green color, and apparently an aggregate of several magnesian minerals. The following is the result of a very careful analysis:

Silica	39.60
Chromic iron	0.20
Alumina	1.94
Protoxide of iron and manganese	8.45
Magnesia	36.90
Water and loss	12.91
	100.00

From this analysis it will be seen that this is a true serpentine, and not unlike, in composition, much of the serpentine of the Atlantic States.

Sandstones and shales.—Upon the serpentine lies a deposit of sandstones and shales, several hundred feet in thickness. They are somewhat interstratified—their strata conformable, and apparently belonging to the same geological epoch, being members of a group widely spread over the Pacific coast, and to which, under the name of San Francisco group, I shall frequently have occasion to refer.

The sandstone, where it has been long exposed to the action of the weather, is light brown in color; is soft and easily worked, having considerable resemblance, both in color and consistence, to the sandstone of which the older public buildings at Washington, D. C., are constructed. From its color, and the facility with which it yields to atmospheric action, out-cropping ledges of this stone closely imitate the brown and irregularly rounded masses of protruded trap, which are so common in California and Oregon; and it has often happened to me to be, at first sight, deceived by the similarity. When, however, this rock has been penetrated to a considerable depth, it is found to become much harder and darker, being grayish-blue in color, and exceedingly dense and resistent, again resembling an erupted rock.

No analyses have been made of these varieties to determine the nature of the chemical change which gives rise to the obvious differences in physical character, but I suspect it is due to the removal, by solution, of the soluble salts which it contains, and especially to the oxidation of the salts of iron. It is also probable that, where it is most dense, it has in some degree experienced the metamorphic action of the igneous rocks which it covers. Both sandstones and shales generally effervesce with acids, and probably contain both lime and magnesia.

This sandstone forms the slopes of the axis lying between the Bay of San Francisco and the ocean, and the rocky basis upon which the city of San Francisco rests. It is quarried near water-level, at the foot of Telegraph hill; and is found skirting the shores of the bay on both sides of the entrance to the Golden Gate, as well as the strait leading into San Pablo bay. It forms the greater part of the islands of Yerba Buena, Alcatraz, and, as I am informed, the western declivities of the Contra Costa mountains.

Shales.—The shales, to which I have referred, are fully exposed in the excavations made in cutting the streets through the elevations which occur in the upper part of the city. They are

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greenish or yellowish-brown in color, and contain varying proportions of clay and sand. Where laid open in the upper part of the city, they are very friable and easily removed; but in localities where less affected by the action of the air, they are considerably more compact, and closely resemble some of the older clay slates.

I was not able to detect in the immediate vicinity of San Francisco, either in the sandstone or shale, any other fossils than small particles of carbonized vegetable matter; but on San Pablo bay this group is highly fossiliferous, and, on the Pacific side of the San Francisco axis, great numbers of an extinct species of *Scutella* (*S. interlineata*) are washed out by the waves from a sandstone similar, in its lithological characters, to that underlying the city. I have little doubt that the sandstones which flank the serpentine axes of southern California, and which contain great numbers of *Scutellae*, *Ostreae*, *Pectens*, and other shells, regarded by Mr. Conrad as Miocene, are of the same age, and, perhaps, continuous with the sandstones and shales of San Francisco.

The sandstone which I have described is the only rock which will furnish a material suitable for architectural purposes in the immediate neighborhood of this city. As a building stone it does not rank high. The softer portions, though easily worked, are too friable to retain any ornament or inscription, or to resist the crushing force of great weight; while that which is quarried from a greater depth, though hard, tough, and handsome, when first taken out, will be liable to fade, and, probably, to a comparatively rapid decomposition. The demand for a good building material which now exists in the city, and which will hereafter be more sensibly felt, can, however, be fully supplied from the stores of granite, porphyry, trachyte, and trap, which are to be found in the Coast Ranges and Sierra Nevada in the greatest abundance, and at points neither remote nor inaccessible.

Jasper.—In a great number of localities in the vicinity of San Francisco, ridges and masses of red jaspery rock are seen. It crops out in the vicinity of the Presidio, on the south side of the Golden Gate, and exists in large quanties at Point Diablo, and thence to Saucilito, on the north side. It is also found in Raccoon straits, and on the southwest side of Angels' Island forms Red Rock, and also occurs at various points further northward. It frequently occurs in ridges, having the appearance of an erupted rock, protruded along lines of upheaval. It is red, yellow, or green in color, but oftenest blood-red, or some intermediated shade between that and pink, being usually somewhat mottled, clouded, or striped.

Veins of white quartz, generally small, traverse it in every direction, and, where it is weathered, it is often peculiarly cellular, ragged, and rough. Where stratified, the laminae which it exhibits are twisted and contorted in all possible directions, and whatever is the history of the material of which it is composed, whether it is thrown up from below or, as is more probable, it is a metamorphosed form of the associated rocks, it is evident that it has been subjected to a high degree of heat. These jaspery rocks are, equally with the serpentines, a marked feature of the geology of the Coast Ranges, from the Gulf of California to the Columbia.

Surface geology.—The hills about San Francisco are covered with loose and, in some places, drifting sand, which has, apparently, in greater part, been derived from the shore of the Pacific, whence it has been driven by the strong and ever-blowing westerly winds. Along the shore of the bay, in many places, alluvial deposits, consisting of sands and clays containing vegetable matter, have collected to a considerable depth. They have probably been formed by the washing down of the higher grounds, and belong altogether to the present epoch.

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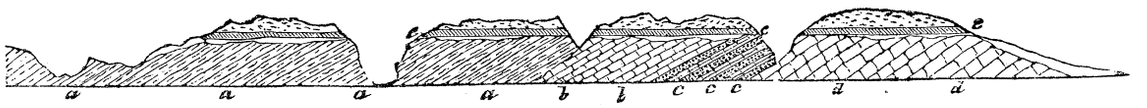
SHORES OF SAN PABLO BAY.

As we go north from San Francisco, passing through the straits leading into San Pablo bay, we find the shore on either hand composed of sandstone, forming elevated ridges, which have been produced by subordinate lines of upheaval, having the same general trend as those which include them. In the channel stands "Red Rock," a mass of jasper, to which allusion has already been made, at the entrance to San Pablo bay. Bird island is a mass of sandstone, as are the points on both sides.

Passing the low land above point San Pablo, and going eastward toward the straits of Carquines, along the south shore of the bay, a most interesting section of strata is exposed, having a thickness of at least 3,000 feet. These strata have an inclination of from 30° to 35°, dipping to the east, apparently from the axis which forms the eastern shore of the straits connecting San Francisco and San Pablo bays.

Sandstone.—The most westerly and lowest member of the series is a somewhat massive, but softish sandstone, similar to that of Bird island, the straits, and San Francisco; apparently here, as below, destitute of fossils. This is succeeded by a series of finer grained, soft sandstones and shales, which contain great numbers of fossil shells. Above these fossiliferous beds ensues a great thickness of conglomerates and tufas, extending to the Straits of Carquines.

SECTION OF STRATA EXPOSED ON SOUTH SHORE OF SAN PABLO BAY.



a a a a, Stratified tufas. *b b*, Sandstones and shales. *c c c*, fossiliferous strata. *d d*, Sandstones. *e e*, Oyster shells.

Fossils.—The fossiliferous shales and sandstones to which I have referred, if they are, as seems probable, the equivalents of those associated with the sandstone of San Francisco, afford us the first satisfactory evidence which we have of the age of the group to which they belong; and they therefore become of special interest in the study of the geology of this region. The circumstances under which I visited the locality did not permit me to give as much time to the examination of these beds, nor to collect so full a suite of their fossils as I thought their importance demanded; it is, therefore, to be hoped that some one who shall hereafter have the time and opportunity may make these strata the subject of special study.

Pecten bed.—My attention was first called to the fossiliferous beds by noticing a stratum, which may, perhaps, be called a shell-limestone, about 4 feet in thickness, which was composed almost exclusively of Pectens. From its superior hardness it had resisted the action of the waves, which had cut deeply into the softer strata, and stood out like a wall, breast high, across the beach, and running, like a reef, far out into the shallow waters of the bay. The strike of these strata, as indicated by the direction of the projecting edge of this stratum, is northwesterly, and generally accordant with the trend of the adjacent axes of elevation.

The Pectens contained in this bed include at least two species: one, a small one, of which I was able to obtain numerous specimens, since described by Mr. Conrad under the name of *P. Pabloensis*, (Pl. III, fig. 14;) the other is very large; some individuals being more than six inches in diameter, but so involved in the rock that I was unable to bring away more than fragments, not enough from which to describe it. It considerably resembles a large species procured from the Miocene deposits of southern California, by Mr. Blake, and called by Mr.

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Conrad *Pecten Nevadanus*, and is, perhaps, identical with it. It seemed to me, however, in the widely expanded alae, in the unusual curvature of both valves, and in the very angular and striated costae and intercostal spaces, to exhibit differences from any species known. Beside the *Pecten*, I found in this rock numbers of a large *Mactra*, of which I could obtain no entire specimens, but which closely resembles *M. densata*, from the Miocene at Santa Barbara, and described and figured (Pl. III, fig. 12) in this report.

Lying immediately upon the pecten bed, are several strata of a soft, yellowish-brown rock, composed of nearly equal parts of clay and sand, and containing large numbers of shells; the smaller species of *Pecten* mentioned, (*P. Pabloensis*) with *Mactra*, *Natica*, *Nucula*, and *Tellina*. These beds are each 5–10 feet in thickness, and compose, perhaps, 50 feet of strata. Upon them lies a thicker stratum of coarse, but soft, non-fossiliferous sandstone, which is succeeded by other fossiliferous strata resembling, in fossils and lithological characters, those below it. Specimens of all these beds containing fossil shells, when examined under the microscope, exhibited no traces of infusoria.

Tufas and marls.—These fossiliferous strata, which have an aggregate thickness not exceeding 100 feet, are followed by a succession of relatively thin and perfectly conformable beds of conglomerate, soft, harsh, coarse sandstones, containing masses of scoria and pumice, concretes, tufas and marls, white, cream, bluish, greenish, yellow, and brown in color, in which I was able to detect no fossils, and which have an aggregate thickness of 1,500 to 2,000 feet.

These strata are evidently of volcanic origin, consisting of ashes, sand, mud, pumice, and scoria, which have been apparently discharged into water, perhaps of considerable depth, and accurately stratified by sedimentary deposition.

To strata of similar character I shall have frequent occasion to refer, as they are found in a great number of widely separated localities, and sometimes stretch continuously over large areas, constituting one of the most remarkable features in the geology of not only those parts of California and Oregon which were visited by our party, but, as I learn from various sources, of a large part of the region lying west of the Rocky Mountains.

These beds uniformly overlie, and are more recent than the tertiary deposits, and bring the geological history of the western coast down to, and, as it seems to me, probably through the drift.

Oyster beds.—A very interesting feature in the section exposed on the south shore of San Pablo bay, is a bed of recent shells which lies horizontally upon the edges of the inclined strata which I have described, at an elevation of some 20 feet above the present level of the water in the bay. This bed is about four feet in thickness, and composed of shells of species now living on the neighboring Pacific coast. They consist principally of *Ostrea*, with great numbers of *Mytilus*, *Lithodomus*, *Pholas*, &c.

The *Lithodomi* are found in the holes which they excavated in the rocky bottom of the water in which they lived. The shells are generally very perfectly preserved; the *Mytili* and *Lithodomi* having lost the epidermis in all cases, and the shells being tender, and somewhat chalky; but the *Ostreæ*, in many instances, retain the colors which characterize the living specimens.

This bed of recent shells affords a striking proof of the disturbances which this volcanic, and earthquake-shaken coast has experienced.

The cause which produced the difference between the present and former relative levels of the surface of the water in the bay and its shores was not merely local in its action; for a similar bed of shells occurs at something like the same altitude around the north and western shores of

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the bay; and the shallows of the southern and eastern parts of San Francisco bay contain a similar bed of dead oyster shells.

It might be supposed that this change in the relative level of the land and water had followed the opening of the Golden Gate to a greater depth than before, and by this means depressing the water level without seriously disturbing the general level of the surrounding country. This theory is, however, untenable, for it would require that the bays of San Francisco and San Pablo should be bodies of fresh water, to which the waters of the Pacific would scarcely have access; while we know, from the fact that this extensive bed of shells is composed of marine species, that the water in which they lived was salt. We may go still further and say that these beds of *Ostrea*, *Mytilus*, *Pholas*, &c., could scarcely be formed in San Pablo bay at present, from the relatively large admixture of fresh water derived from the Sacramento and San Joaquin rivers. It seems scarcely possible that a sufficient amount of salt water could ever have been supplied to these oyster beds through the narrow channel of the Golden Gate, and it is probable that the oysters of San Francisco bay, which are still submerged, were destroyed rather by a want of salt water than a change of level.

The presence of these shells above the level of San Pablo bay is, therefore, due to an elevation of the land, and not to a subsidence of the water. Dr. Trask (*Report on Geol. Cal.*, 1854, *p.* 27) mentions this oyster bed as occurring on the north shore of San Pablo bay at the height of 30 feet above high tide. On the south shore it is not over 20 feet above high water mark. In San Francisco bay it is still submerged. Although oysters are not necessarily always found at a fixed distance below the surface, we may infer, with considerable certainty, that the center of action and the greatest elevation was north of San Pablo bay.

On the west side of San Pablo bay occurs an interval of shore, which is very low, and seems connected with a depression in the general surface, which extends far to the westward. It is said this depression is continuous to Bodega bay, and that no part of it rises 50 feet above the ocean level. If this is true, San Pablo bay doubtless communicated directly with the ocean through this channel—a channel subsequently closed by the elevation which has been described, but which, when open, would have afforded a more abundant supply of salt water than they now have to the marine molluscs of the bay.

STRAITS OF CARQUINES.

The Bay of San Pablo is, in fact, but a continuation of San Francisco bay, and occupies a portion of the same great trough lying between the most distant of the nearly parallel axes of elevation which have been mentioned as determining the outline of the valley of San Francisco bay, viz: the Mount Diablo axis, and that forming the immediate coast of the Pacific. A subordinate anticlinal, a kind of shoulder of the Contra Costa range, crowds itself down into this great basin, and narrows a portion of the bay into the strait which connects the wider expanses of water which have received, for convenience, distinct names. As we traverse the bay of San Pablo, and approach its eastern boundary, we reach another barrier, which has opposed the drainage of the great Californian valley, through which, as at the Golden Gate, the waters of the Sacramento and San Joaquin have forced or found a passage. This barrier is formed by a continuation north of Mount Diablo of the Mount Diablo range, which, though greatly reduced in elevation, and considerably interrupted and divided, is still plainly distinguishable, trending about northwest, till it loses its identity in the numerous parallel ranges of the coast mountains. I was not able to examine the geology of the Straits of Carquines so closely

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as to determine the nature and relative position of all the rocks which are exposed there; nor was I able to carry my observations uninterruptedly from the section exposed on San Pablo bay to that of the straits. The shores of the upper part of the straits I found to consist of a great number of alternations of thin-bedded argillaceous sandstones, very similar to some of those exposed on the south shore of San Pablo bay, and precisely like those of the western shore on Point San Pedro, above San Rafael, and those of Rincon point, south of San Francisco.

These sandstones are inclined at a very high angle, some of them being nearly vertical, but not having a uniform dip. One, and perhaps more than one anticlinal crosses the straits in the general trend of the range. I was not able to detect any fossils in the rocks there exposed, but have no doubt of their identity with the San Francisco group, having the same geological age with those of San Pablo bay, and therefore Miocene or more recent.

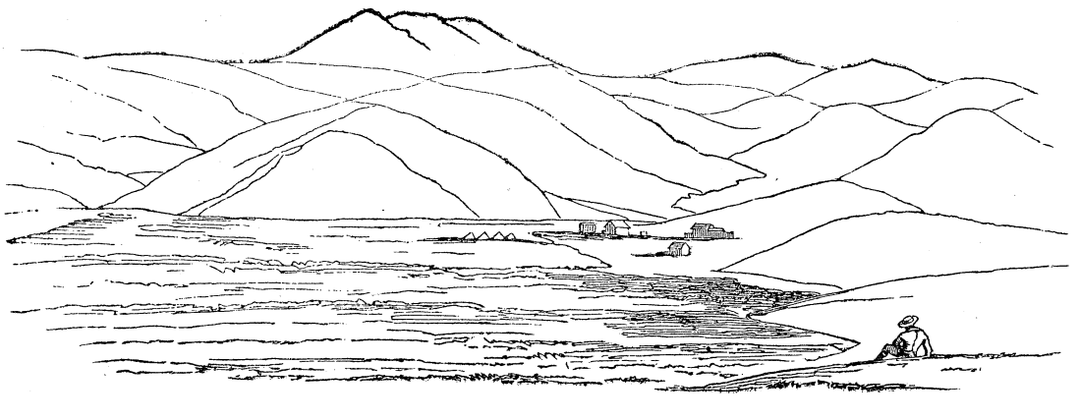
I saw no evidences here or below of the existence of the older slates which have been said to exist in this vicinity. Nor did I see here, or anywhere on the shores of San Francisco or San Pablo bays, with the exception of a single locality, the Golden Gate, any trap, trachyte, or other unmistakable plutonic rock.

The greenish argillaceous sandstones of the Straits of Carquines have threads and sheets of gypsum running through them in all directions, a feature shared by the similar strata in the localities which I have mentioned, Point San Pedro, &c.

BENICIA.

The geology of the vicinity of Benicia is apparently but a continuation of that of the Straits of Carquines. An anticlinal crosses from near Martinez to the vicinity of Navy Point, on either side of which are found sandstones, shales, &c., the apparent equivalents of the San Francisco group. There is, however, a conglomerate at Navy Point which presents somewhat different characters from those of San Pablo bay, the pebbles which it contains consisting in a great degree of fragments of the harder silicious rocks, jasper, hornstone, agate, carnelian, &c. Though I had little opportunity of examining it, my impression was that it did not present a new element in the geology of our route.

At Navy Point Mr. W. P. Blake, geologist of the Pacific Railroad Survey in southern California, under Lieut. Williamson, U. S. A., discovered teeth of sharks, which give to these strata a date certainly no older than the Miocene. I did not notice any fossils in any of the rocks about Benicia; but it is probable they would reward a more thorough search than I was able to make.



SANDSTONE HILLS NEAR BENICIA.

Sandstones.—The high hills which border the straits and occupy all of the area between

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Vallejo and Benicia, and which, with their wavy and graceful outline and their unbroken mantle of wild oat, present a view so peculiar and so pleasing, are all composed of the San Francisco group of sandstones; at least such was the inference which I derived from my examination of them. Immediately back from the town of Benicia the sandstone is considerably massive and thick bedded, and has been extensively quarried as a building stone, for which it serves a very good purpose, but is open to the objections suggested when speaking of a similar stone at San Francisco. When exposed in ledges it has a most striking resemblance to trap. About Major Vaughn's rancho, two miles northwest of Benicia, where we were encamped for some days, the only rocks visible are a soft grayish sandstone, generally somewhat massive, and thin layers of greenish brown shales, some of which are soft, and where exposed are often covered with an efflorescence of sulph. alumina. These beds are dipping in different directions in the different localities where examined, and are evidently traversed by several lines of uplift.

Five miles northwest from Benicia, among the rounded sandstone hills, the most elevated summit in the vicinity is crowned by a crest of red jaspery rock, similar to that which occurs so abundantly at Point Diablo, near San Francisco. This crest is particularly rough and rugged, is nearly half a mile in length, and has the general trend of the ranges of hills which surround it, and of the Mount Diablo mountains. It is somewhat cellular and spongy in texture, and projects forty to sixty feet above the softer rocks which flank it. It exhibits no tendency to stratification, as far as I examined it, and has all the external characters of an injected dyke of plutonic rock which owes its relief to the erosion of the softer material which once formed its enclosing walls. The junction of the sandstones with the jasper is covered by debris and not visible; but where exposed in the vicinity, though much disturbed, they exhibit no marks of metamorphic action.

Warm spring.—At the north end of this ridge of jasper is a copious spring, which seems to issue from immediate contact with the rock. The water is strongly charged with sulph. hydrogen, and is slightly thermal, having a higher temperature at its source than in the basins which it fills, a few rods down the hill-side. I had no thermometer with which to test its temperature, but supposed it to be between 80° and 90°. No silicious or calcareous deposit is made by it. It has the common taste of sulphur water, and is habitually used by a family residing near.

In a ravine near by, lenticular nodules of argillaceous iron ore are interstratified with the thin layers of greenish, soft, fine-grained sandstone.

Soil.—The country about Benicia is generally productive, though its value as an agricultural district, in common with the whole of the interior valley, is greatly impaired by a want of water. The soil, which is formed by the decomposition of the argillaceous sandstones of the San Francisco group, is dark, deep, and rich. The surface is thrown into hills, often rising several hundred feet, but in gentle swells and slopes, with smooth and graceful curves, never presenting a broken outline. And this surface, as far as the eye can reach, is covered with the wild oat, (*Avena fatua.*) No peculiarity of the soil, but atmospheric influences have given to this region such a prevalence of annual vegetation, and limited its trees to the few scattered clumps of evergreen oak, (*Quercus agrifolia,*) which, so much resembling orchards, combine with the unbroken stretches of wild oat to give to it the appearance of being universally and thoroughly cultivated.

MOUNT DIABLO.

While encamped near Benicia, this mountain, which we had first seen when entering the Golden Gate, was in plain view from our camp. Its altitude is 3,760 feet, while its base is at

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the sea level. Of its geological structure no account has yet been given, and it was not ascended by our party. Its base, and perhaps its principal mass, is composed of the series of sandstones which have been so fully described in the preceding pages. Specimens brought from the higher positions of the mountain, which I had the pleasure of examining, show that with tertiary sandstones, trap, serpentine, and diallage occur, but on what relative positions and quantities I could not ascertain. Its structure, however, can scarcely be a matter of doubt. It marks a conspicuous focus of action in the elevation of the Mount Diablo or Contra Costa range, which we know has the same general structure as that of the range immediately bordering the coast; having probably the same date, and, like the coast mountains, having not constant but characteristic axes of serpentine, flanked by thick beds of tertiary sandstone and shale, frequently associated with which are jasper, diallage, and actinolite.

Some of the tertiary beds of Mount Diablo are highly fossiliferous, containing the same assemblage of genera, and probably of species, which are so characteristic of the coast mountains in southern California. Among the most striking of these fossils is an immense oyster, which is apparently the same with that figured and described p. 72, Plate IV, fig. 17 and 17*a*, of this report, and called by Mr. Conrad *Ostrea Titan*.

Gold has been found in small quantities in the streams flowing from Mount Diablo, and it was at one time supposed that the diallage brought from there contained this metal, and a quantity was transported to San Francisco, for the purpose of extracting the gold from it. Little or none was found, however, and the error of the first experiment is said to have resulted from employing mercury which had been before used in extracting gold, not all of which had been separated from it.

SUISUN BAY.

North of Mount Diablo the range of mountains which has received its name is somewhat divided and broken. This has offered a convenient avenue through which the drainage of the upper country could be carried; and through this the Straits of Carquines have been cut. The waters of the great Californian valley, somewhat impeded in their flow to the ocean, and falling to high tide level long before reaching the Golden Gate, accumulate above the straits, forming Suisun bay, and the *tulé* marshes at the junction of the Sacramento and San Joaquin.

From Benicia to Goodhues, four miles, the north shore of Suisun bay is formed of the sandstones which have been so fully described.

Calcareous tufa.—Near Goodhues occurs a deposit of calcareous tufa, which has been quarried out and burned for lime. It is very pure and white, and would undoubtedly make an excellent mortar.

From this point to Cordelia, the hills bordering the bay are all composed of some kind of volcanic rock. The most abundant forms are soft and tufaceous, reddish or bluish gray; other portions are harder, either scoriaceous, compact, or vesicular trap.

Above Cordelia, on Suisun creek, the rock which forms the hills, bordering the road, is a hard, tough, umber-colored trap, which seems to be the prevailing rock over a large area in this vicinity.

It would make a very good building stone, and, though wrought with more difficulty than the Benicia sandstones, would be far more strong and durable, and to many eyes more pleasing.

Soil.—The soil of the shores of Suisun bay is black, and evidently highly productive, but the area of level land below Cordelia is relatively small, and of that a considerable portion is

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marshy. The sandstone hills are covered with wild oats and cultivated to their summits, but the trap ranges are rough, rugged, and valueless.

SUISUN VALLEY.

This valley is enclosed between two ranges of hills, of which those on the west are high and rough, and formed of vesicular trap; while those on the east are low, rounded, and apparently composed of sandstone.

Near where we crossed the eastern hills to Vacaville, a deposit of calcareous tufa was noticed, similar to that at Goodhues.

At Lagoon lake, and in that vicinity, the sandstones are fully exposed. I was able to discover no fossils, but the rock is identical in appearance with that at Benicia, and is doubtless the same.

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CHAPTER II.

GEOLOGY OF THE SACRAMENTO VALLEY.

General features.—Structure of the coast mountains.—Trap, serpentine, and granite.—Auriferous slates.—Structure of Sierra Nevada.—Older than coast mountains.—Metamorphic limestone.—Auriferous rocks.—Placer deposits.—Alluvial plain.—Local geology.—Vacaville to Chico creek.—Gravelly plains.—Alluvial soil and terraces of Putos and Cache creeks.—Banks of the Sacramento.—Red color of Yuba river.—Want of stone at Marysville.—Sacramento buttes.—Chico creek.—Fossiliferous sandstone.—Interesting mingling of fossils.—Strata probably cretaceous.—Trap hills.—Streams absorbed by the plain.—Volcanic phenomena.—Lava streams.—Crater.—Obsidian.—Fort Reading.—Trap hills.—Tufaceous conglomerate.—Cretaceous rocks near Shasta city.—Ammonites Batesii.—Carboniferous limestone.—Fossils.

GENERAL FEATURES.

The area which has received this name constitutes the north half of what might properly be called the great Californian valley, forming a continuous trough, lying between the converging axes of the two great ranges of Californian mountains, and of which the northern and southern halves would be inseparable were it not that, draining to the centre, they are respectively traversed by the rivers Sacramento and San Joaquin; and hence, for convenience, have been distinguished from each other by the names of these streams. This great valley, which has a length of 350 miles, and a maximum breadth of 50 miles, may be regarded as affording in its structure and origin a typical example of the manner in which—formed by common causes—all the principal valleys of the far west have been produced. All may be said to occupy the elongated areas enclosed between the separated but inosculating ranges of mountains, having nearly the same common trend.

Of these valleys the Gulf of California is the most southern and the largest. Though its floor is now below the ocean level, and its mountain boundaries do not quite enclose it, it presents a marked similarity of general structure to the others to which I have alluded—the valleys of San Francisco and Sacramento—and, to carry the comparison still further, to the second double valley, that of the Cowlitz and Willamette.

The mountain chains which enclose the Sacramento valley are the coast mountains on the west, and the Sierra Nevada on the east. Between these it lies as a broad plain, of which the central portion is scarcely raised above the level of the sea, while the remote ends are scarcely more than twice as many feet above as they are miles distant from the centre. The greater part of the fall of the draining streams being confined to the vicinity of the ends of the valley, as a consequence, through most of the length, the current of these streams is slow, their course tortuous, and their borders, especially near their point of exit, are marshy and covered with wide expanses of *tulé*, (bullrush.)

Surface and soil.—The centre of the valley is occupied by a broad alluvial plain, with little diversity of level, of which the soil is generally fine and fertile, but sometimes coarse, gravelly, or stony, and barren. The more fertile surface is covered with a growth of wild oat, or grasses,

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interspersed with a great variety of flowering annuals, while the gravelly and more unproductive portions support a thinner growth of coarser plants, (*Eryngium*, *Hemizonia*, *Madária*, &c.) Of trees, there are none, except such as grow in narrow lines along the streams. These belts of timber are of varying breadth, from a mile or more, of wide-spreading magnificent oaks, (generally *Quercus Hindsii*,) to a meager border of willows, poplar, or sycamore, hung with festoons of grape along the water's edge.

Bordering the central plain on either side is a second "bench," or terrace, generally less than 100 feet above the lower, and which sometimes, by erosion, thrown into low rounded hills, oftener forms a distinct prairie plain. Crossing this upper terrace toward the mountains we soon rise into the foot hills, which are covered with groves and clumps of oak, with here and there scattered trees of the nut-pine. The scenery of the foot hills is frequently picturesque and beautiful, with its lawn-like slopes and clumps of spreading oaks, presenting views which might well serve as models for the landscape gardener.

The agricultural capabilities of the different parts of the Sacramento valley, though considerably influenced by the structure and constituents of the soil, are more directly dependent on the degree in which its greatest want—the want of water—is supplied. With an abundance of this indispensable element, it would be one of the most productive portions of the globe.

COAST MOUNTAINS.

The structure of the coast mountains, where they form the western border of the Sacramento valley, is apparently similar to that of the same ranges in the vicinity of San Francisco, which has already been described. They form a belt thirty to fifty miles wide, composed of several associated ranges, and having an altitude of from 3,000 to 5,000 feet. They are composed, for the most part, of volcanic rocks, trap, trachyte, pumice, with occasional protrusions of granite and serpentine. The flanks of these mountain ranges on either side are interruptedly occupied by tertiary sandstones, and by volcanic marls and tufas of still more recent date—the sandstones containing characteristic Miocene fossils; the finer marls containing infusoria, generally of fresh water origin.

Near Tomales bay a bed of whitish limestone occurs, highly metamorphosed, exhibiting no fossils, and as yet of unascertained age. Specimens of a limestone containing no fossils were also collected by Lieutenant Abbot near Yreka. There are in many localities on the coast mountains, particularly near the north end of the Sacramento valley, metamorphic slates, sometimes auriferous, which are probably of ancient date; but this is only conjecture, as they have, so far, yielded no fossils.

SIERRA NEVADA.

The structure of the eastern wall of the valley of the Sacramento has not yet been fully made out. It is, for the most part, composed of the same geological constituents as the coast mountains, having an origin due to the same general system of elevation, and probably nearly the same date, *i. e.*, subsequent to the deposition of some of the tertiary strata. I should, however, be disposed to regard the Sierra Nevada as having had an existence, and the greater part of the range as having been above the level of the ocean previous to the deposition of the San Francisco sandstone, which is so characteristic of the coast mountains, and which, if it can be identified in the Sierra Nevada, is probably confined to its flanks, at a low level.

A metamorphic limestone is found at intervals throughout all that part of the Sierra Nevada which skirt the California valley. Its age has not been determined, as it is generally highly

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crystalline and metamorphic, and contains no fossils. From its relations to the limestone discovered by Dr. Trask, near the base of Mount Shasta, and which is of carboniferous age, one may suspect it to belong to that era.

The great mass of the Sierra Nevada is composed of plutonic or volcanic rock, granite, gneiss, mica schists, and porphyrys, trap, trachyte, &c., with auriferous talcose slates, and veins of quartz. These strata, having been extensively broken up and eroded by aqueous or glacial action, have, in the re-arrangement of their constituent materials, given rise to the *placer* deposites which skirt the base of the range. The deposition of this comminuted material has apparently been effected by aqueous agency, and controlled in a degree by the law of gravitation, as the gold, the heaviest of the component materials, is found at or very near the bottom. The surface of the plain which lies between these ranges of mountains is underlaid by beds of transported material—gravel, clay, and tufaceous conglomerate—several hundred feet in thickness, which were once deposited as sediments on the bottom of the trough, but have been extensively re-arranged by the present water-courses, and in many places subjected to considerable disturbance from volcanic action.

LOCAL GEOLOGY.

VACAVILLE TO CHICO CREEK.

After leaving the foot hills of the coast mountains, we traversed the valley diagonally to the vicinity of its eastern margin. Making this transit, we were constantly upon the alluvial deposits which have been referred to, and nowhere found any rock in place on the immediate line of our march. Between the base of the hills, near Vacaville and Putos creek, the surface passed over formed low hills and table land composed of gravel, entirely destitute of trees, but covered with a thin coating of the grasses and other plants which have been mentioned as characteristic of the gravel surfaces of the valley. The soil has apparently but little fertility, and is nowhere grazed or cultivated. The pebbles which compose the gravel beds are generally of small size, well rounded, and consist of jasper, quartz, porphyry, trap, &c. As we approached Putos creek the soil became fine, loamy, and fertile, and on the banks of the stream supported a narrow belt of magnificent oaks.

The banks of the stream are distinctly terraced, the upper bench being some 25 feet above the lower, which is about the same distance above the bed of the creek. The material of which these lower terraces is composed is principally a fine alluvial earth, mingled with which are a few pebbles. The upper terrace consists in greater degree of pebbles, some of which are of considerable size, much rounded, and, like those found in the bed of the stream, composed of trap, jasper, and quartz.

Cache creek.—The interval lying between Putos and Cache creeks is similar in its features to that south of the former. The immediate vicinity of Cache creek, however, is a region of great fertility; the soil is dark and deep, and the belt of timber which borders the stream is wider, and the trees even finer than those of Putos creek. These differences are doubtless mainly due to a more abundant supply of water afforded by Cache creek.

Its banks are alluvial, the bed gravel, the current rapid, and the water clear and good. The terraces of Cache creek are not as perceptible as those of the Putos, the upper bench being further removed from its immediate banks. The region lying between the crossing of Cache creek and the Sacramento, at Knight's Landing, is very level and nearly all under cultivation. Unlike the country previously traversed, we found this not covered with wild oats or dried

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grass, but everywhere sustaining a growth of *green* vegetation, except where covered with the ripening wheat. A great breadth of surface was occupied by this crop, which the farmers told me generally produced from 35 to 40 bushels to the acre. The drought of the present season would reduce the yield to 25 to 30 bushels.

The banks of the Sacramento, at Knight's Landing and at Frémont, where we crossed it, are composed of fine alluvial earth, generally about 30 feet above the water-level at that time. A belt of timber lines either side; that near the water being willow, poplar, and sycamore, bound together by grape vines; further back the long-acorned oak, which, when the trees are crowded, assumes the form of the white oak of the forests of the eastern States.

No terraces are visible in the immediate vicinity of the Sacramento. Like those of Cache creek, its banks have been formed by the stream when at nearly its present level, and belong entirely to the present era.

The water of Feather river, at the junction with the Sacramento, is so highly charged with sediment, derived from the gold diggings on its tributaries, that it is rendered quite opaque, and has a color as decided as that of the rivulets in the streets of our towns during a thunder-shower.

The country bordering Feather river to Marysville presents no new geological features. No rock is seen in place, and the banks of the stream are like those of the Sacramento, composed of fine loamy earth, with very few pebbles as large as walnuts. The soil is excellent, and melons and various crops are growing with considerable luxuriance.

The red color of Feather river, so noticeable at its junction with the Sacramento, is for the most part, derived from the Yuba, which, at Marysville, where they unite, has deposited such quantities of sediment as to render its navigation impossible at a point considerably below where boats could formerly run.

The floods of the Yuba, which have occasioned so great destruction of property at Marysville, have left piles of drift-wood forty feet above its bed.

The want of building stone is severely felt in this vicinity. The houses in the town, since the fires have swept away relays of wooden structures, have been all built of brick, and the wharf at the steamboat landing is built of bags of sand.

From Marysville, up the feather river, to Hamilton, we found no rock in place, and no transported masses of any considerable size. The soil is generally a fine sandy loam near the river, evidently fertile, and supporting a dense growth of vegetation; while the plains back from the streams are frequently gravelly, and less productive, bearing a thin crop of coarse grasses, and scattering trees of the two species of oak which have been mentioned, with occasional clumps of *manzanita*.

The gravel and rolled stones in the beds of the streams are generally composed of some form of trappean rock, usually trap, porphyry, trachyte, &c., more rarely of quartz. These are, probably, principally derived from the Sierra Nevada, but in part also from Sutter's buttes, which are but about 10 miles distant from the road which we followed.

These mountains have been distinctly visible since leaving Cache creek; first as a single peak, subsequently showing two others. They form, however, but a single mountain mass, and should be denominated by a common name. From specimens brought from there, as well as from the description given of them by Professor Dana, (Geol. Expl. Exped.,) we learn that they are of volcanic origin, and not of recent date.

They now rise like islands in the plain on which they stand, the highest point having an altitude of about 1,800 feet above its general level. The alluvial deposits of the valley, which

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surround their bases, exhibit little traces of disturbance, and do not cover their sides; from which it is apparent that they were not covered by the waters by which these transported materials were deposited.

We have here arrived at nearly the eastern limits of the Sacramento valley. The foot hills of the Sierra Nevada are but few miles distant, and although immediately on Feather river, we are still on the lower alluvial plain which borders the Sacramento river, and occupies all the central portion of the valley within a mile to the north; the surface rises more than 200 feet, and a series of rounded hills commence, which are so characteristic of the borders of the valley.

Chico creek.—No rock was found in place from Hamilton, where we left Feather river, to this point. The surface is somewhat undulating; the higher grounds being destitute of trees, the soil gravelly and unproductive, while the lower grounds immediately adjacent to the streams which we crossed are fertile, and sustain groves of oak timber.

The beds of the streams contain gravel and rounded stones in larger quantities than those before passed, and the fragments are of larger size. They consist principally of trap, compact or vesicular, some of it being scoriaceous.

Fossils.—At Bidwell's on Chico creek we saw fragments of calcareous sandstone—brought from a locality not far distant on the same stream, in the foot hills of the Sierra Nevada—which contained great numbers of fossils very perfectly preserved. The rock in which they occur is light brown in color, and quite hard and compact. The fossils are exclusively marine shells, and present an interesting mingling of forms, to which attention was first called by Dr. Trask, in the Proc. Cal. Acad. Sciences. The genera represented are *Mactra*, *Tellina*, *Nucula*, *Fusus*, *Turritella*, *Natica*, &c., of which the species are as yet undetermined, with the exception of two—a *Mactra* and *Nucula*—considered by Mr. Conrad as probably identical with two species, *Nucula divaricata* and *Mactra albaria*, described by him in the Geology of the Exploring Expedition, and obtained by Professor Dana from the shales and sandstones near Astoria, on the Columbia river.

The Astoria shales contain large numbers of fossils, many of which have been described by Mr. Conrad, (op. cit.) and have been regarded by him as of Miocene age. These shales and sandstones are also probably identical with the San Francisco group, which, as we have seen, may for still other reasons be considered as recent as the Miocene epoch.

Baculites and *Ammonites* have never heretofore been found in any strata of more recent date than the cretaceous, and there these genera have been regarded as furnishing the most certain criteria by which to distinguish between cretaceous and tertiary deposits. There can be no doubt, however, of their occurrence in the sandstones of Chico creek, and, from their mode of fossilization, could not have been transported from older deposits, but must have lived in the sea with the other associated genera.

The *species* of the fossil shells found with the *Ammonites* and *Baculites* in this locality are probably all new, unless the *Nucula and Mactra* alluded to are, as has been supposed, identical with those of Astoria. They are, therefore, of little or no value in determining the age of the deposit within the limits in question.

The *genera* represented are, perhaps, equally common in cretaceous and tertiary rocks, and, so far as known, do not afford any forms which, though specifically new, might be regarded as by their general pattern to indicate a cretaceous rather than a tertiary age, or *vice versa*.

One of two conclusions is therefore inevitable: either the *Nucula* and *Mactra*, which are supposed to link these strata to others known to be Miocene tertiary, are distinct from those of the shales of Astoria, and the Chico creek strata are cretaceous; or they are identical, and *Baculites* and *Ammonites* cease to be criteria in distinguishing tertiary from cretaceous rocks.

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In either case the facts are of great interest, as indicating the presence of cretaceous rocks in a region where they had never been suspected to exist, or proving a new and important truth in palæontology. While a careful study of the fossils of Chico creek will alone solve all the problems which they suggest, it may be said that the evidence is still wanting upon which we must discard one of the most authoritative axioms of palæontology, and believe that the cephalopoda of the chalk continued to inhabit the Californian coast throughout all of the Eocene, and part of the Miocene tertiary periods. There are certainly no *living* species among those yet found in the Chico creek strata, and although much stress is laid by Dr. Trask (*Proc. Cal. Acad. Nat. Sciences, vol. I,*) on the recurrence there of living *genera*, it is a well known fact that a large part of the genera of the chalk are still represented in our seas. It is probable, too, that Mr. Conrad would not insist on his identification of *Nucula divaricata* and *Mactra albaria*, as the specimens submitted to him were few and imperfect. It may also be ultimately proven that the argillaceous standstones of Astoria are *not* of Miocene age, for although having very much of a Miocene look, none of the species are found in the present seas, nor in other known Miocene strata. For the present, therefore, with unmistakable *Baculites* and *Ammonites*,* with no recent, and but two doubtfully *Miocene* species, the evidence is in favor of these strata being cretaceous rather than tertiary.

CHICO CREEK TO FORT READING.

Above Chico creek the Sacramento valley rapidly narrows ; that portion lying east of the river forming a nearly level plain, four to six miles wide, from which the foot hills of the Sierra rise abruptly. Between Antelope and Deer creeks I crossed over to the hills at a place where a stream coming down from the mountains, and at its point of entrance into the valley passes through a magnificent gate, of which the side walls are at least 500 feet in height. The rock in the vicinity is all a dark basaltic trap, which has been accumulated by successive overflows from some volcanic vent, probably not far distant. These lava floods, where exposed in sections, present a stratified appearance, some of the beds being imperfectly columnar. Though exhibiting very strikingly the phenomena of volcanic action, these trap hills are not of recent date, but were probably formed synchronously with the upheaval of that part of the Sierra Nevada with which they are connected.

The stream which flows through this opening in the hills in the rainy season is evidently of considerable size, and at the point of entrance into the valley was, at the time of my visit, (July 19,) still flowing, and contained large numbers of fish ; yet long before it reached the Sacramento its waters were absorbed by the arid plain traversed by its channel, and where we crossed its bed, near the river, it was perfectly dry, a gravelly trough containing not a drop of water.

Our route from Antelope creek to Fort Reading lay across the hills which sweep around from the Sierra Nevada and, uniting with the foot hills of the coast mountains, form the northern boundary of the Sacramento valley. These hills we found composed exclusively of volcanic rock, generally a dark vesicular trap, which forms rough and ragged crests, divided by deep and narrow ravines, of which the sides are precipitous, or covered with angular blocks and fragments, among which we made our way with difficulty. In several places we passed over sheets of lava, which looked as though it had been but a few years since in a fluid state, the surface

*Mr. F. B. Meek writes me that he also finds *Inoceramus* in the Chico creek rock, and is inclined to regard it as upper cretaceous.

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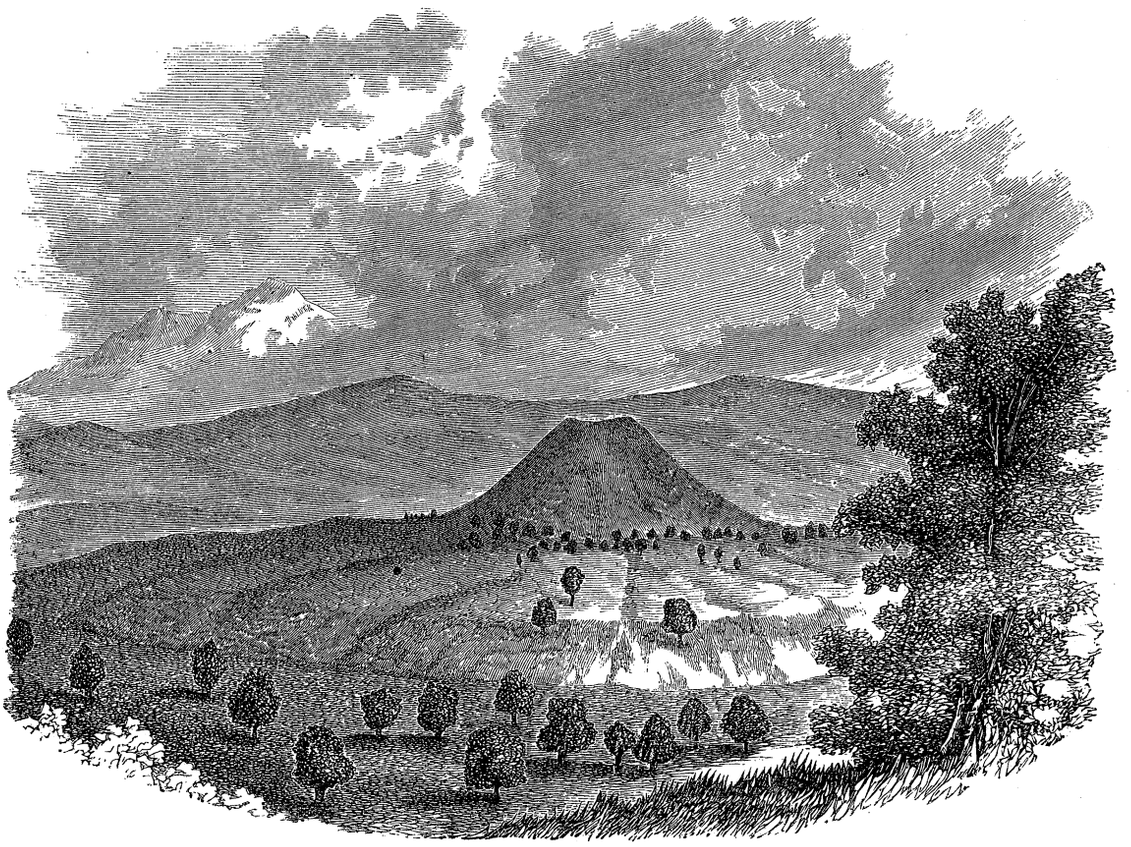
still bare, and exhibiting all the waves and eddies of a flowing stream. Some of these trappean rocks were apparently older. Among them were porphyry, trachyte, and volcanic breccia, in which the imbedded fragments formed masses of several hundred pounds weight. No drift action has modified the surface of these rocks; but, with the exception of the marks of atmospheric weathering, which they exhibit in different degrees, they are as rough, and their surfaces as fresh, as though but recently formed. The thin soil which covers or surrounds them is derived only from their decomposition, and is often highly colored by oxide of iron. It seems to possess the inorganic elements of fertility, and sustains among the rocks a vigorous growth of wild oat.

On the north side of Bear creek valley is a more striking proof of the comparatively recent date of volcanic action in this vicinity than even the lava streams. This is furnished by a volcanic cone 500 or 600 feet in height, which has a crater on the summit, and of which the sides are covered with reddish scoria.



VOLCANIC CONE NEAR FORT READING.

On Bear creek black obsidian occurs in considerable quantities, and some of it was brought me, as "probably some kind of stone coal."

The trap ranges in this vicinity, of which I have spoken, form high and sometimes precipitous banks to the Sacramento river, with but little level land between them, and constitute the entrance to the almost continuous cañon through which it flows for nearly a hundred miles.

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FORT READING.

The geology of the vicinity of Fort Reading is not unlike that of the region lying immediately south of it. The valley of Cow creek, in which it is situated, is bounded by ridges of trap, of the brown and cellular variety, which is stereotyped in all this region. The trough between these ridges is partially filled with a stratified deposit which is very soft, light gray in color, and contains scattered lumps, of small size, of fine white pumice.

There is little doubt that this deposit is tufaceous in character, and is composed of the lighter and finer products of volcanic eruptions, rearranged by aqueous agency. It is probably of recent date, and synchronous with somewhat similar beds which are found in various portions of California, and are more recent than the tertiary *cretaceous rocks*.

A few miles southwest of Fort Reading, at Arbuckle's diggings, a locality which I was not able to visit, strata occur which are undoubtedly of cretaceous age. *Ammonites*, in considerable numbers, have been obtained there by Dr. Bates, of Shasta city, and a very handsome species has been described by Dr. Trask, (*Proc. Cal. Acad.*, *vol.* 1, *p.* —,) under the name of *Ammonites Batesii*.

To the occurrence of cretaceous rocks in this locality I shall have occasion to refer again in a subsequent part of this report.

Carboniferous limestone.—In sight from Fort Reading is a group of mountains, bearing east of north, which, as we learn from Dr. Trask, are in a considerable degree composed of limestone, which he has described in his Report on the Geology of the Coast Mountains, 1855, p. 50, and which he regards as the equivalents of the upper carboniferous rocks of Iowa, &c.

The limestones of these mountains, as described by Dr. Trask, have a great thickness and are highly fossiliferous. While in San Francisco I had the pleasure of seeing through glass the fossils procured by Dr. Trask from this locality, and although the number of species collected is small, and they are probably all new, and cannot, therefore, be regarded as perfectly conclusive criteria in deciding on the age of the containing rock, there seems to be little question that they belong to some portion of the carboniferous group. Whether they are synchronous with the upper coal strata or the sub-carboniferous limestone is a question which cannot be definitely settled until a greater amount of material has been collected.

These fossils consist of small spirifers, orthis, encrinal stems, and cyathophylloid corals.

The lithological characters of the rock are not unlike those of the sub-carboniferous limestone of the Allegheny and Mississippi coal fields, but no value whatever can be attached to the resemblance.

It is very desirable that this deposit of limestone should be fully examined, and its fossils carefully studied by some one who is sufficiently familiar with carboniferous palæontology to determine accurately the relations which it sustains to the carboniferous rocks of the valley of the Mississippi. With its great thickness it may very well be the representative of the entire carboniferous series of the east; the open sea in which the carboniferous limestone was deposited here continuing open sea, while the coal measures were being formed on the immediate shores of the continent of that period.

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CHAPTER III.

GEOLOGY OF THE WESTERN RANGE OF SIERRA NEVADA.

RELATIONS OF WESTERN RANGE OF SIERRA NEVADA TO MOUNT SHASTA AND THE SIERRA NEVADA OF CALIFORNIA.—GENERAL GEOLOGICAL RELATIONS OF MOUNT SHASTA.—COAST LINE ONCE FORMED BY THE SIERRA NEVADA AND CASCADE MOUNTAINS.—SUCCESSIVE STAGES IN THE ELEVATION OF THE CONTINENT.—CONTINUITY OF THE COAST MOUNTAINS.—TRANSVERSE CHAINS.—LINES OF FRACTURE DIVERGENT FROM MOUNT PITT AND MOUNT SHASTA.—CARBONIFEROUS LIMESTONES OF MOUNT SHASTA, PERHAPS CONTINUOUS WITH THE METAMORPHIC LIMESTONES OF THE SIERRA NEVADA.—LOCAL GEOLOGY.—TRAP PLATEAUS ABOUT FORT READING.—COAL NEAR MCCUMBER'S FLAT.—RECENT VOLCANIC ROCK AROUND THE BASE OF LASSEN'S BUTTE.—LASSEN'S BUTTE A VOLCANIC CONE.—LAVA PLAIN ON CANOE CREEK.—CHIMNEYS.—SUBTERRANEAN GALLERIES.—TRAP PLATEAUS AT THE MOUTH OF CANOE CREEK. INFUSORIAL MARLS ON BANKS OF PIT RIVER.—BEDS OF ROUNDED STONES UNDERLYING MARLS.—TRAP FORMING THE WALLS OF THE LOWER CAÑON OF PIT RIVER.—MOUNTAIN OF METAMORPHIC SLATE.

FROM Fort Reading we passed southward of the limestone mountains mentioned in the last chapter, and following a course little north of east, crossed that portion of the Sierra Nevada which connects Lassen's butte with Mount Shasta; coming down on to Pit river, at the upper end of its long cañon or series of cañons, formed by its passage through this chain of mountains. Some differences of opinion have prevailed in reference to the relations which this range sustains to the Sierra Nevada on the one hand, and to Mount Shasta on the other; but it has been generally regarded as a spur of the Sierra Nevada running off at a considerable angle with the main trend of that chain to connect with Mount Shasta. It has also been supposed that eastward of Mount Shasta the main range of the Sierra Nevada would be found extending northward and connecting directly with the Cascade mountains of Oregon. Mount Shasta has even been claimed as a portion of the coast mountains, and is so represented by Dr. Trask, (*Geol. Report*, 1853, *p.* 48.)

Dr. Trask also suggests that the Sierra Nevada terminates at Lassen's butte, and that the coast mountains, when continued northward, form the Cascades of Oregon and Washington Territories.

Both these hypotheses seem to me untenable. So distinct a line of upheaval connects Mount Shasta with Lassen's butte, and Lassen's butte with the Sierra Nevada, that they all seem to form the inseparable parts of a single mountain system.

As has before been stated, the geological data are still wanting for determining with precision the relative ages of the Sierra Nevada and coast mountains; but the evidence, as far as it goes, is altogether in favor of the greater antiquity of the Sierra Nevada, and of the connection of Mount Shasta with the older system. The most characteristic fossiliferous strata of the coast mountains have not yet been found in the Sierra Nevada.

The physical structure of the country traversed by these mountains teaches the same lesson. The Sierra Nevada, including Lassen's butte and Mount Shasta, form the wall which bounds the elevated plateau. The eastern bases of these mountains are four thousand feet above the western, and it seems difficult to resist the conclusion that at one stage in the elevation of the continent the mountains I have mentioned, with the Cascades of Oregon, formed its western

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limit, and that anterior to the emergence of the Californian valley or the coast mountains, the ocean dashed its waves against a continuous iron-bound coast, formed by the great Californian range. Of this coast Mount Shasta was a high and prominent headland.

With the subsequent elevation of the coast mountains, the entire western portion of the continent was doubtless considerably raised, and, like the higher, the lower terrace was bordered by mountain ranges, which presented to the Pacific a second continuous wall, on which its waves, though borne on by all the accumulated momentum of their long and unobstructed course, are still impotently beating.

I think we have evidence, derived from various sources, that the elevation of the western coast continued long after it reached the present level, and that since its maximum height was attained it has suffered a depression of many hundred feet. I shall, however, have occasion to return to this subject when speaking of the Cascade mountains, and will, therefore, leave it till the facts there to be gained can be brought to bear upon it.

The continuity of the present coast mountains of California and Oregon can scarcely be doubted. The fossiliferous sandstones of Monterey, Santa Clara, San Francisco, Port Orford, Coose bay, Astoria, and the Cowlitz, are all apparently of the same age. Though presenting marked local peculiarities, they have a common character both in their lithological features and in their fossils, and are to be referred to a common period—certainly not older than the Miocene.

In going from the mouth of the Columbia to San Francisco by sea, the coast seems formed of a continuous mountain chain, which is constantly in sight, and which produces, throughout nearly the entire distance, a bold, rocky, "iron-bound" shore. To this general rule the limited areas of level land in the valleys of the Umpqua, Coquille, Rogue, and Klamath rivers, form scarcely an exception.

As far north of San Francisco as Cape Mendocino the coast mountains have the same general northwest trend; and a more plausible supposition than that the Cascades form the continuation of the coast mountains would be, that the latter ranges terminate at Cape Mendocino, and that the coast mountains of Oregon were a continuation of the Sierra Nevada. It is not necessary to suppose this, however, but it is sufficient to consider the coast mountains of Oregon as the coast mountains of California deflected from the trend which they preserve below Cape Mendocino, and that the ranges of the coast and of the interior inosculate on either side of the parallel of 42° in the Calapooya, Umpqua, and Siskiyou mountains.

The structure of these subordinate ranges has as yet received but little attention from geologists, though it presents some very interesting problems, which, aside from their bearing on the local geology of the far west, will perhaps throw some light on the question of the synchonism of parallel axes of elevation, and the constancy of trend in the same line of upheaval.

Nor is the question of the relations of Mount Shasta to the coast mountains or Sierra Nevada one of merely abstract interest, but of the highest practical value in determining the relative age of these two mountain systems, and especially in fixing the age of the metamorphic limestones and slates of the Sierra Nevada, which as yet have yielded no fossils. If, as seems probable, the fossiliferous limestones of the mountains connected with Mount Shasta shall prove to be continuous with the limestones of the Sierra Nevada, referred to above, they will, perhaps, serve as a key by which to unlock the whole structure and age of the great "Californian range."

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LOCAL GEOLOGY.

Our journey over the base of Lassen's butte to the basin of Pit river was productive of little geological information, except of the monotonous prevalence of recent volcanic rocks over all that portion of this mountain chain which we traversed.

From Fort Reading to McCumber's, some twenty-five miles, plateaus and ridges of dark vesicular trap extend in unbroken and unvaried succession. Here we had an inkling of some facts of high geological interest, but were unable to remain long enough to settle the questions raised by the information received. Mr. McCumber has found coal, as he says, of good quality, in the hills a few miles distant from his rancho. Of this coal he had then no specimen, and could tell me nothing of the character of the associated rocks, but represented the bed to be thick and extensive.

This information, though vague and unsatisfactory, was, as it seemed to me, highly important, as proving the existence of beds of coal at this elevation and distance from the coast.

McCumber's flat is about 4,000 feet above the sea, and the deposits of coal represented to be several hundred feet higher, probably at least 4,500 feet above the sea level. It is, perhaps, possible that the tertiary lignites of the coast recur here, but no tertiary rocks are known to exist within many miles of this locality; and the lignites of Santa Clara on one side and Coose bay on the other, are the nearest deposits of what could, with any propriety, be termed coal. Taken in connexion with the fact of the occurrence of carboniferous limestone a few miles northwest from McCumber's, and this limestone having a rapid easterly dip, indicate at least a possibility that the coal of this vicinity may be carboniferous. A single hand specimen would have decided the question, but that could not be obtained; and since the promise of Mr. McCumber to send into Fort Reading specimens of the coal was not kept, the problem is yet unsolved, whether the tertiary lignites of California and Oregon are the only coals found on the Pacific coast.

If these carbonaceous beds should prove to be of the same age with those referred to, the fact would be scarcely less important, and would perhaps materially aid us in the solution of some of the problems which the geology of the far west still presents.

After leaving McCumber's, we found the dark vesicular trap, which prevails over so large an area around Fort Reading, mingled with, and in many places entirely superseded by, volcanic rock of different character. Immediately east of McCumber's we passed a surface, a mile or more in extent, over which the vegetable soil covered rolled and rounded fragments of pumice and a light-colored felspathic lava. These boulders had, apparently, formerly occupied the broad bed of a water-course, from which the supply of water had long since been cut off by some of the convulsions of this volcanic region. That this change of course in the stream was not of recent date, is proved by the accumulation of soil on the surface and the dense growth of large trees which it supported.

Lassen's butte is evidently a volcanic cone, and one whose fires have not been long extinguished. Its summit is distinctly crateriform, as will be seen from the accompanying cut, and is capped with perpetual snow, and has an altitude of about 9,000 feet. Below the snow line for 1,000 feet the mountain is bare of vegetation, and covered with piles of lava, or slopes of ashes.

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The geology of all this region bears the record of intense and recent volcanic action. The surface crossed before reaching the summit of the pass was covered with blocks of scoriaceous trap, pumice, trachyte, or porphyry. The prevailing rock at the highest part of our route is a friable felspathic lava, which readily disintegrates, forming a white sand, which reflects the sun almost like snow. This rock is lying in rough and ragged masses, in many places bare of vegetation, and of recent origin.

LASSEN'S BUTTE, FROM THE NORTH.

The open space about the base of Lassen's butte is doubtless due to the fires which, from time to time, sweep through these pine forests, yet a large area in its vicinity is overspread with volcanic products, evidently of so recent date that it seems not improbable that it has been in a state of activity since many of the pines which are growing on its base began their existence.

This accumulation of modern volcanic matter completely conceals all underlying rocks, and gives an uninteresting monotony to the geology of the surrounding region.

On Canoe creek, a tributary of Pit river, we found the first of the "Sage plains," which form so constant a feature of the central desert. They here present arid surfaces of but limited extent, bounded by cliffs, or ledges of trap, and covered with a light volcanic soil, which rose in clouds of dust as we passed. Scattered bunches of grass, clumps of *Artemisia*, and a few trees of yellow pine, comprise all the vegetation which their sterility does not exclude.

As we descended Canoe creek we entered a region where volcanic phenomena are displayed on an extended scale.

This stream traverses a valley expanding towards the north, bounded by walls more than a thousand feet in height, composed of dark lava-like trap or red scoria, the interval between them

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forming a nearly level lava plain, a kind of congealed sea, of which the surface was everywhere roughened by waves cooled while flowing; their crest black and ragged; the troughs containing a little ash-like soil, which supported a tangled growth of "sage" and "manzanita."

At numerous points on this lava plain we passed miniature volcanic vents or chimneys, which had evidently been formed by the bursting out of steam or gases from below, and in more than one instance we noticed subterranean galleries, or caverns, having a diameter of fifteen to twenty feet, an irregularly circular section, and extending indefinitely in either direction.

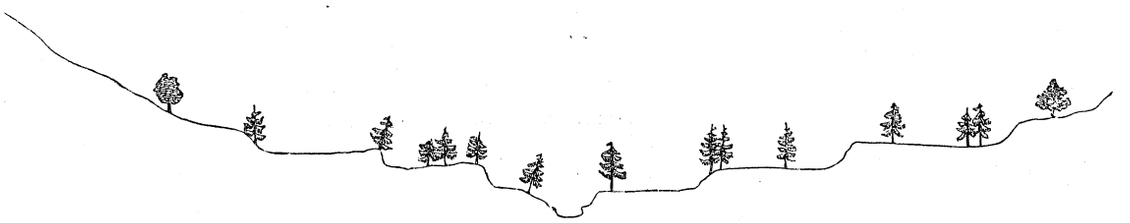
In some places the roofs of these passages had fallen in, permitting a full examination of their internal structure. They seemed to be conduits through which streams of lava had continued to flow when surrounded by a congealed and solid crust. They may in some cases have been modified by currents of water running through them, but it seems impossible that their origin could be due to the action of any such agent.

Similar galleries have been described by Prof. Dana and Dr. Winslow as occurring on the lava plains of the Sandwich Islands, and they seem to be a constant feature in the phenomena of great overflows of lava.

The chimneys to which I have referred probably communicated with these passages.

An oasis in this barren waste was formed by a stream of pure cold water, which issued from the cavernous wall bounding this plain on the east, ran half a mile, in many winding, life-giving channels, then fell into a chasm and disappeared.

The geology of the region bordering Canoe creek throughout its course is exceedingly monotonous. Cliffs, ridges, or tables of dark scoriaceous trap border it on either side, from the crossing of the emigrant trail to its mouth. Near its junction with Pit river, the tables of trap occurring on its banks exhibit a remarkable symmetry. They form a series of nearly level plateaus gradually rising in successive grades and receding from the stream. They terminate towards Canoe creek in abrupt, frequently mural edges, and present the same arrangement on both sides of it, as represented in the figure.



TRAP PLATEAUS BORDERING CANOE CREEK.

Infusorial marls.—The banks of Pit river, both above and below the mouth of Canoe creek, are partially formed of regularly stratified sedimentary deposits; the first seen since leaving the valley of the Sacramento.

They appear on both sides of Pit river at intervals for several miles, being in many places interrupted or covered by beds of trap. They are, perhaps, best exposed in the cañon formed by the passage of the river through "Stoneman's ridge," the most conspicuous of the lines of upheaval, which form what is known as the lower cañon of Pit river.

They here exhibit a thickness of about fifty feet, but are considerably tilted up, and are covered by a thick bed of trap, which has been poured out over them.

They exhibit narrow and parallel lines of deposition, but are very homogeneous, and can hardly be said to form more than two distinct beds. Of these, the upper is white and fine as

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chalk, resembling very pure kaolin, derived from the decomposition of crystalline felspar. The lower bed is light brown, or dirty white in color, and has a slightly gritty feel between the fingers.

These strata rest upon a thick bed of rolled and rounded fragments of trap, porphyry, and basalt, of all sizes, from masses of two and even three feet in diameter to pebbles. They are generally as large as one's head, and great numbers are each a foot in diameter.

The surface of this bed of boulders is, perhaps, twenty feet above the present surface of the stream; but it bears indubitable evidence of having at one time been covered by it, or, at least, the stones composing it, so large and clean, have been rounded where they lie by a current or waves of water.

The appearance presented by this bed of boulders is different from that of any of the beds of volcanic conglomerate, which are so common in many parts of California and Oregon, or of the stratified conglomerates of the Sacramento valley, and it is undoubtedly of local origin. The trap which formed the greater part of the bank above is evidently of recent date; more recent than the infusorial marls, and the marls more recent than the conglomerate, and the conglomerate an accumulation of rolled stones and pebbles, which belongs to the present epoch. The trap which overlies the infusorial marls composes a large part of the walls of the cañon at this point, where it has been much cut away by the stream, and forms nearly perpendicular faces of several hundred feet in height. The soft nature of the underlying strata has, however, very much assisted in its removal.

On the south side of the cañon and overlooking it is a mountain, which forms the most prominent point of Stoneman's ridge in this vicinity. It is conical in form, and has the outline of a volcanic peak, but I found it to be composed, from base to summit, of metamorphic slate.

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CHAPTER IV.

GEOLOGY OF PIT RIVER AND KLAMATH BASINS.

PIT RIVER BASINS.—LAKE-LIKE CHARACTER OF THE LOWER BASIN.—PROOFS THAT IT HAS ONCE BEEN A LAKE.—INFUSORIAL SEDIMENTS DEPOSITED BY ITS WATERS.—RANGE FORMING THE UPPER CAÑON OF PIT RIVER.—SECOND BASIN OF PIT RIVER.—INFUSORIAL MARLS.—HILLS OF METAMORPHIC SLATE, GREENSTONE, PORPHYRY, AND TRAP BORDERING PIT RIVER.—GEOLOGY OF THE COUNTRY ABOUT THE HEAD OF PIT RIVER.—HOT SPRINGS AND INFUSORIAL MARLS.—KLAMATH BASINS TYPICAL ILLUSTRATIONS OF THE GEOLOGICAL STRUCTURE OF A GREAT AREA.—COMMON FEATURES OF THE REGION LYING EAST OF THE SIERRA NEVADA AND CASCADES.—NOT ONE BUT MANY BASINS.—KLAMATH BASINS ONCE LAKES.—LOCAL GEOLOGY.—PIT RIVER TO WRIGHT LAKE.—RECENT VOLCANIC CONE.—CLIFFS RORDERING RHETT LAKE OF SANDSTONE AND TRAP.—EFFLORESCENCE ON THE SHORES OF RHETT LAKE.—THE NATURAL BRIDGE A FAULT.—INFUSORIAL MARLS OF LOST RIVER AND LOWER KLAMATH LAKE.—METAMORPHIC FORM OF THESE MARLS RESEMBLING JASPER.—GEOLOGY OF THE SHORES OF KLAMATH LAKE.—BASALTIC CONGLOMERATE ON KLAMATH RIVER.—INFUSORIAL MARLS.—PUMICE.—TRAP RANGES SOUTH AND EAST OF KLAMATH MARSH.—PUMICE PLAIN BETWEEN KLAMATH MARSH AND THE DES CHUTES RIVER.

LOWER BASIN OF PIT RIVER.

FROM the summit of the conical mountain, which I have mentioned as overlooking the entrance to the lower cañon of Pit river, we for the first time looked down into one of the series of areas which give character to the immense region which has been denominated the Great Basin. This conical mountain formed a portion of a subordinate axis of the range we had crossed, and of which Lassen's butte forms the most elevated point. This range constitutes the western wall of the first of the basins of Pit river, and runs off with a northwesterly trend in the direction of Mount Shasta, which was plainly visible from the point where we stood.

In the east rose from this plain another wall, similar to that which I have described, and having nearly the same trend. Toward the south, these two ranges coalesced, and were lost in the peaks composing the Sierra Nevada. On the north low ranges of mountains bounded the horizon, but the exact limits of this plain, in that direction, could not be determined. Its surface seemed as level as water, and, but that it was covered with grass, it had every appearance of a large lake, enclosed on every side by bold and rocky shores. The only exit from this wide area, as proved by its drainage, is through the deep chasm which Pit river has formed in its western wall.

It required no stretch of the imagination to see that, at a comparatively recent period, this basin had been what it now so much resembled, a lake, whose waters had gradually been withdrawn through the deepening channel of its present draining stream. As we descended to the plain, our conjectures of its history were confirmed by its geological structure. Its surface, which is nearly level, is everywhere underlaid by a series of fine infusorial marls, similar to that which occurs in the cañon of Pit river. These marls are apparently horizontally stratified, and as the channels of the streams which cross the plain have cut them to a depth of but a few feet, it was impossible to determine their thickness. Exposed at various points, they exhibited great uniformity of color and texture, being pure white or light brown, and all of them containing, in large quantities, the remains of fresh water *Diatomaceæ*. In the examination of the structure of this basin, many points of analogy with that of the Sacramento valley suggested themselves. It has the same elongated form, is bounded by similar parallel mountain ranges, having nearly the same trend. It is drained by streams which unite in the same way to force a

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passage through its eastern wall. The sediments deposited by its waters, which form the surface over which we passed, though for the most part undisturbed, and nowhere exhibiting the rearrangement which marks most of the sediments of the Sacramento valley, closely resembled the strata of fine infusorial marls which are found in various parts of that valley, and which seems at one time to have stretched over a large portion of its surface.

RANGE FORMING UPPER CAÑON OF PIT RIVER.

The geological structure of this range presents a striking similarity to that which connects Lassen's butte and Mount Shasta. The dark vesicular trap, which forms the lower cañon of Pit river, here reappears, and almost without exception or variation forms the mass of the range where we crossed it. Through this barrier Pit river has forced its way in a narrow and somewhat tortuous cañon, of which the perpendicular walls present sections frequently several hundred feet in height. The surface rock on the north side is everywhere the dark vesicular trap to which I have referred, and of which the exposed surface in many places retains the form and appearance which it had when in a melted state. It is often bare; at other times covered with a thin soil, which has been formed by its decomposition. It presents very few level surfaces; is covered with a thin growth of coarse grasses, with here and there a dwarfed tree of the western cedar. On the south side of the cañon the rock is generally similar in character, but near the middle of the range I noticed a mass of red and apparently recent scoria.

SECOND BASIN OF PIT RIVER.

Descending the eastern side of the range of which I have been speaking, we came down on to a second plain, similar in all respects to that which lies westward of it. It has nearly the same breadth, about twenty miles; its longest diameter being parallel to the mountain range which borders it, its limits north and south not being visible from any point of our route. Like the lower basin, it is very nearly level, and lies at an average altitude of a little over 4,000 feet, being 800 feet higher than the one we previously crossed. The drainage of this plain is, apparently, less perfect than that of the lower one; it is more moist; covered with a deeper soil, sustaining a more vigorous growth of green grasses; and, from the number of fluviatile shells strewed over its surface, is evidently at some seasons overflowed. We had little opportunity of examining the structure of this plain, but it is apparently generally underlaid by infusorial marls similar to those already described. In the vicinity of the hills which border it on the east these marls appear in various localities, considerably elevated above its level, and have, apparently, been subject to some disturbance since their deposition. The most common form which they here present is precisely like that which occurs in the lower cañon of Pit river, being as fine and white as chalk, and like that abounding in the remains of fresh water infusoria. Associated with this are strata of soft green sandstone, which occurs in thin beds interstratified with the last.

The hills of which I have spoken, as forming the eastern limit of this plain, scarcely deserve the name of mountains, and in the imperfect examination I was able to give them I was unable to detect the course of the lines of upheaval by which they had been formed. They exhibit considerable variety in the rocks which compose them, which are, however, all erupted or highly metamorphic. A dark compact basalt, greenstone, and porphyry are all present, and among the boulders found in the bed of Pit river, apparently derived from these hills at a higher point in its course, I found jasper, agates, quartz, granite, porphyry, and obsidian. The hills which

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we crossed immediately after leaving Pit river, on our route to Klamath lakes, are composed of a blue, hard, highly metamorphosed silicious slate. A few miles further north occurs a beautiful variety of porphyry, of which the ground work is chocolate color, the crystals of felspar, white, and of large size. In a greenstone dyke, near the same locality, I found small quantities of green carbonate of copper. The plutonic rocks exposed on Pit river, where we left it, are apparently older than the floods of lava-like trap which have covered so much of the country traversed before reaching that point. Here, rather than anywhere else on the line of our route to the Columbia, I should expect to find veins of quartz and talcose slates, which are so frequently the repositories of gold. From the rolled fragments brought down by Pit river, as well as from specimens brought in by our hunters, who followed the river to a higher point than where we left it, it is evident that there exists in this vicinity a protrusion of granite, and associated with it, the porphyries, quartz, greenstone, &c., of which I have spoken.

Beyond this range of hills Pit river traverses, and rises in, a region which, over a large area, exhibits precisely the same features as that through which we have followed it.

Lieutenant Williamson, while connected with an exploring party which visited this vicinity some years since, followed up Pit river to its source, and traversed the plain in which Goose lake is situated. from his detailed and clear description of the country I learn that the white, chalk-like marls, which form so marked a feature of the geology of the lower plains of Pit river, recur at various points near its source above, as below, in lake-like plains, which are separated by walls of volcanic rock. The plain about Goose lake is of the same general character with those we have passed over. Pit river takes its rise in a series of hot spring, which, in their character and surroundings, apparently resemble those of the Des Chutes Basin, to which I shall soon have occasion to refer.

From a gentleman whom I had the pleasure of meeting at Fort Reading, and who had recently passed over the country lying between Fort Hall and Goose lake, I obtained valuable information, and specimens illustrative of the geology of his route. From these it is evident that the geological structure of the region bordering lower Pit river affords a complete illustration of that of a large portion of country lying east of it.

KLAMATH BASINS.

Like the plains of Pit river the several areas, in which are set Wright, Rhett, and the Klamath lakes, exhibit the typical features of the structure of the entire region with which they are inseparably connected, and which, with very imperfect notions of its character, has been denominated the Great Basin. This immense area, cut in various directions by ranges of low mountains and hills, has, by this and other causes, been divided into many subordinate districts, each of which, possessing some characters peculiar to itself, has, also, many features which are common to all. They all form portions of the same great plateau to which allusion has already been made, and which exhibits everywhere a remarkable unity of geological structure, of climate, and in its flora and fauna.

Of the many secondary basins which go to make up this area, those which lie nearest the base of the mountain wall, on the west, receive a larger share of the rain precipitated upon it than those which are more remote. As a consequence, the supply of water received through the year is greater than the annual evaporation, and this excess flows off in the streams which lead from them. At a period not very remote in the history of our continent, the amount of water falling into the Klamath and Pit river basins was, probably, much greater than now,

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and coverd, to a considerable depth, surfaces which are now exposed. The streams which flowed from these areas had greater volume, and flowed from a higher level than at present. To this cause we may attribute the deep channels which they have cut through the resistant material of the mountain barriers which opposed their progress to the ocean.

In all their general features, the basins of the Klamath lakes closely copy those of upper Pit river. They form elongated troughs, lying between nearly parallel mountain ranges, of which that on the west is broken through by Klamath river, which reaches the ocean through a cañon as deeply cut as that of Pit river. The bottom of this trough is covered—to how great a depth we do not know—by a series of stratified deposits, altogether similar to those which I have described. The drainage of this basin has, however, been less complete than that of the Sacramento and upper Pit river, and large portions of its surface are still occupied by bodies of water.

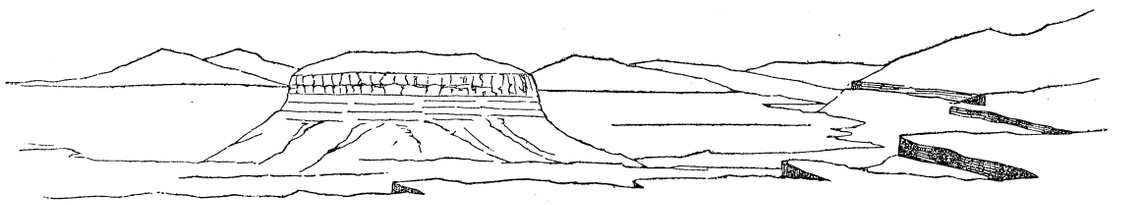
LOCAL GEOLOGY.

The geology of the interval between Pit river, at the point where we left it, and Wright lake, is exceedingly monotonous. Four or five miles north of Pit river we lost all traces of the older volcanic rocks, to which I have referred as occurring in that vicinity; and from that point, northward, for thirty miles we passed over a succession of plateaus of vesicular trap, precisely like that which occurs so abundantly about Fort Reading, this being apparently the form which the volcanic material always assumes when poured out in floods of considerable depth on to surfaces not covered by water.

Near Wright lake occurs a conical mountain of trap rock, which rises to a height of perhaps 1,500 feet from the plain on which it stands. The south shore of this lake is bordered by a mountain range of nearly equal altitude, which has here a course nearly east and west; curving round towards the north, its western extremity terminates in a bold headland on the shore of Rhett lake, and is connected by a low ridge, with similar hills, lying north of these lakes. This connecting ridge, forming the barrier between Rhett and Wright lakes, is composed exclusively of trap, and bears on it a conical hill of blood-red scoria, which has evidently at no distant day formed a volcanic vent.

Rhett lake is bordered on the east and north by cliffs of considerable height, of which the base is composed of light-colored sandstone, the upper portion of trap. This sandstone, which is very soft and friable, belongs to the series of infusorial marls of which I have so frequently spoken.

On the eastern shore of the lake is a conical hill, considerably removed from the cliffs referred to, but having apparently the same structure. It is composed at base of sandstone, regularly



HILL OF SANDSTONE, CAPPED WITH TRAP, RHETT LAKE.

stratified, and nearly horizontal, and is capped with trap. Both the trap and sandstone were doubtless once connected with the similar strata in the cliffs, now nearly half a mile removed. We have here evidence of an amount of erosion which can hardly be attributed to the action of

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any cause now operating, and it is quite certain that the surface of the surrounding country—like all that which we traversed west of the Cascade mountains—has never been swept by a drift current. I can only explain it by connecting it with the presence of a much larger quantity of water in this basin at a former period than is found here now.

In that portion of the Klamath basin through which Lost river flows, the same sandstone is found interstratified with infusorial marls, which are fine and white. At the "Natural Bridge" these strata have been thrown up by a fault, and form a dam across the stream, where it is forded. The sandstone here contains black scoria in rounded masses, frequently as large as an egg. In this respect, as well as in texture, it resembles a sandstone forming part of the series of tufaceous marls, described in Chapter I, as occurring on the south shore of the San Pablo bay. Here, as there, the greater part of the material being undoubtedly of volcanic origin, consisting of ashes, comminuted pumice, mingled with masses of scoria, all of which have been thrown into water and stratified by deposition.

I may say, in this connexion, that I obtained from Mt. Hood, in Oregon, volcanic ashes which had been recently thrown out, which would form precisely similar strata, if similarly treated. From Lost river, these infusorial marls underlying the surface of a nearly level plain, extend to and artially surround Lower Klamath lake, reaching as far north as the southern end of Upper Klamath lake. On the shores of Rhett lake, and several localities on the plain, which I have mentioned, the surface is covered with a white efflorescence resembling snow. It is doubtless derived, in a great degree, from the marl beds, which usually contain a notable quantity of soluble salts. Specimens of this efflorescence was remitted to Dr. J. D. Easter for analysis, upon which he has rendered the following report:

"*A white saline efflorescence from Rhett lake, Oregon.*—The salt, freed by solution from earthy and vegetable matter, consisted of sulphates of soda and magnesia, with a considerable proportion of chloride of sodium. A quantitative analysis was begun, but the vessel containing the solution was broken during my absence from the laboratory, and no more of the salts remained. The efflorescence is similar to a large number of specimens which I have analyzed from California and New Mexico."

Across the south end of Upper Klamath lake a low ridge of trap runs, by which its waters are considerably raised above the plain surrounding Lower Klamath lake. On the flanks of the hills which compose this barrier I found the infusorial marls, here highly metamorphosed, some of the specimens approaching jasper in appearance. The hills bordering the lake near its southern end are composed of soft pulverulent sandstone, similar to that found on the shore of Rhett lake, and, like that, composed of thick beds of trap.

The hills bordering Upper Klamath lake are high and bold on either side: on the west, rising in successive grades until they join the Cascades, here crowned by the lofty and symmetrical cone of Mount Pitt; on the east, a succession of trap ranges, having a trend nearly northwest and southeast, terminate in bold headlands which project into the lake and form its shore. These ranges rise to an altitude of twelve to fifteen hundred feet, with valleys of corresponding depth. They are composed of dark vesicular trap, in some places scoriaceous. The most northerly of these interrupted ranges, along the northern base of which Klamath river flows for several miles, is, in a great degree, composed of volcanic breccia, the enclosed fragments ranging in size from two to six or eight inches in diameter.

At the junction of the east branch of Klamath river with the main stream, for some distance along the base of the ridge of which I have spoken, a stratum of infusorial marls is exposed,

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which is white and chalk-like, in all respects resembling that from Pit river and the plains about Lower Klamath lake. A few miles north of this occurs another volcanic ridge, having nearly the same trend with those last mentioned, from which it is separated by the nearly level and, in many places, fertile valley through which Klamath river flows. This ridge is composed partly of dark, compact trap and partly of white and soft pumice, which, in many places, covers the surface, and, in its decomposition, gives rise to a peculiarly light and ash-like soil, upon which nothing seems to flourish but the yellow pine. Through this ridge Klamath river flows in a cañon, of which the walls are perpendicular and two hundred feet or more in height.

North of this ridge is another low and level plain, of which the surface is in many places covered with pumice. Crossing another but lower ridge of similar character, we descend to the shores of Klamath marsh. This lake occupies an area similar in all respects to those below, and like them is formed by the crossing of the general trough in which they all lie, of the transverse trap ranges to which I have alluded. Along the eastern shore these ranges are very conspicuous, several of them running far out into the lake, and throwing its eastern border into a series of long points, alternating with deep bays.

The pumice is here as marked a feature in the geology of the district as the trap; covering all the surfaces, and forming a soil into which the feet of our horses sank so deeply as to render any departure from the trail which followed the outline of the shore very disagreeable. At the north end of the lake, a point of metamorphosed slate projects a few feet above the surface, and forms the only exposure of rock of this character seen within many miles of that point.

The western shore of this lake is formed by a broad prairie scarcely raised above the water level, and doubtless at some seasons submerged. It seemed everywhere underlaid by fragments of pumice, which had apparently been so accurately levelled by the action of the water. This pumice, when pulverized, forms a substance having a striking resemblance to the marls to which I have so often referred, and, aside from the organic structures which they contain, they have doubtless been formed of similar materials.

The interval separating Klamath lake from the head-waters of the Des Chutes river forms a nearly level plain, covered everywhere with pulverized pumice, and supporting a meagre growth of yellow and spruce pine. Both east and west, ranges of hills are visible from the route which we followed, and at various points masses of black basalt project above the general surface. From the porous nature of the soil, the streams which come down from the mountains at the west are soon absorbed, and we were only enabled to obtain water by digging, at a single point on our journey. At this point, the water seems to have been brought to the surface by a dyke of trap rock which impedes its subterranean flow from the west.

A precisely similar surface borders the south fork of the Des Chutes to its junction with the main stream which comes down from the Cascade mountains. On the banks of this latter stream are exposed, in various localities, strata of white, chalk-like marls, and light brown, green, and friable sandstone, in all respects identical with those of Pit river and Klamath basins.

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CHAPTER V

GEOLOGY OF THE CASCADE MOUNTAINS.

PANORAMIC VIEW OF THE CASCADE MOUNTAINS.—SIERRA NEVADA AND CASCADE MOUNTAINS.—A WALL CROWNING THE WESTERN MARGIN OF THE GREAT CENTRAL PLATEAU.—STRUCTURE AND ORIGIN OF THE CASCADE RANGE.—MAIN CREST NEAR ITS EASTERN MARGIN A LINE OF VOLCANIC PEAKS.—MORE WESTERLY MOUNTAINS, METAMORPHIC SLATES.—LOCAL GEOLOGY.—CRATER PASS.—EVIDENCES OF GLACIAL ACTION.—GLACIERS ONCE DESCENDED FAR BELOW THE PRESENT SNOW LINE.—EXTENT OF GLACIERS IN THE CASCADES.—CONDITIONS UNDER WHICH THEY MUST HAVE BEEN FORMED.—BY ELEVATION OR CHANGE OF CLIMATE?—EVIDENCES OF ELEVATION.—SUB-AERIAL EXCAVATIONS OF MOUTHS OF RIVERS.—DEPRESSION OF TEMPERATURE WOULD PRODUCE GREATER PRECIPITATION OF MOISTURE.—STREAMS FLOWING FROM THE CASCADE MOUNTAINS FORMERLY LARGER THAN NOW.—CAÑONS OF THESE STREAMS NOT RIFTS BUT EXCAVATIONS.

AFTER reaching the head-waters of the Des Chutes river, we ascended the main fork of that stream to its source, in the Cascade mountains, spending a month crossing and recrossing the main crest, latitude 44° north, in the vicinity of the Three Sisters. The mountains which have received this name form part of a group of five, of which only the three most westerly are visible from the Willamette valley, and have been known to the residents. The altitude of the loftiest of the group is about 10,000 or 11,000 feet above the level of the sea, the line of perpetual snow being 7,000 feet. This group of mountains marks an angle or joint, if I may use the expression, in the Cascade range. Standing on the summits of the passes between them, we saw the main crest of the range crowned by several peaks of considerable altitude, but particularly marked by the lofty and snow covered cones of Mount Jefferson and Mount Hood, trending away nearly due north. Looking southward, we saw the belt of the Cascade mountains, so broad above, narrowed in its limits, trending southwest by south, marked by no conspicuous peak, and yet continuous to the point where the sharp, snow covered cone and broad base of Mount Pitt bounds the horizon in that direction. There, another joint marks a deflexion of the chain to the south, a course which it holds till lost in the huge mass of Mount Shasta; there again deflected to the eastward, to be again turned south at Lassen's butte. This mountain system seems like some grand fortification, as though Nature, when the broad plateau, which reaches inland from its base, was redeemed from the sea, had built along its western margin a wall of such altitude as should forever bid defiance to the waves, and at all the salient or re-entering angles had planted towers which should strengthen and command the whole.

Looking north from the Three Sisters, and viewing the Cascade mountains in profile, we saw that the axis of the range was set nearest to its eastern border, and that the descent from this crest to the plateau which forms its base in that direction was made by few and steep declivities; while toward the west stretched a broad belt of mountains which gradually diminished in altitude, and, as we subsequently learned, more than fifty miles distant, were lost in the foot hills which border the Willamette valley.

This section seemed to afford us some clue to the manner in which this range had been formed. The series of principal peaks marks the line of fracture in the earth's crust, along which the greatest exhibition of volcanic forces would naturally be displayed. Toward the east, the great

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plateau preserves its general horizontality, only broken by subordinate hills and mountains, which mark the cracks and fissures formed in the convulsions by which it has been shaken.

Toward the west the rocky strata, with many fractures, bent down toward the depression of the ocean's bed, by their broken and upturned edges, had formed the succession of mountain peaks which constitute the great breadth of the chain. The nature of the rock exposed at the various points which we visited seemed to lead to the same conclusion. The line of fracture is marked by a series of volcanic peaks—many of them of great altitude—of which the fires are not yet wholly extinguished; their sides being covered by an immense accumulation of volcanic material, of which the greater part seems as fresh as if thrown out but yesterday. The streams of lava which have poured down their sides now stand bare, black, and ragged, scarcely a lichen even as yet having found a foothold on them. Toward the west the mountain masses are composed of highly metamorphosed slates, set on their edges and inclined at every possible angle.

LOCAL GEOLOGY.

As we ascended the Des Chutes river we soon left behind us the pumice plains and the stratified marls which line its banks, and at an altitude of 4,500 feet entered a region south of the Three Sisters, abounding in lakes, mountain meadows green and fresh, and forests of fir and pine, of different species from those occupying the plain below. The soil in many places was fertile, the scenery as picturesque as can be found in any part of the world. The only rock exposed being a dark vesicular trap, or a nearly black compact basalt.

Ascending to a pass between the snow mountains in the group I have mentioned, we passed over a surface covered with comparatively recent volcanic material, heaped up in the greatest confusion. This we traced to its origin in a crater, half a mile in diameter, which lies between two of these snow mountains, which form portions of its once continuous enclosing walls. The southern rim of this crater has an altitude of 6,500 feet; the northern rim being two or three hundred feet higher. The eruption, of which we saw such evident traces, seems to have taken place from the southern side of the mountain, the crater being here opened by a deep fissure, through which a stream flows from the lakes occupying its centre. The walls of the mountain which border the crater are formed of black lava or blood red scoria, and immense piles of pumice and obsidian, fresh and bare, mark the recent date of its activity.

EVIDENCES OF GLACIAL ACTION.

The north wall of this crater is composed of black porphyry, which is very compact, and apparently older than most of the trap and lava which we saw in the vicinity. This rock, though intensely hard and very homogeneous, everywhere bore the marks of the action of some powerful agent. It was planed down to a smooth and even surface, or scored into deep grooves or furrows, which were sometimes continuous for rods. These grooves ran down the northeast slope of the mountain, were confined to the outside of the crater, and seemed to radiate from a point over its crater. On a subsequent occasion, descending the mountain toward the southwest, we traced these grooves for several miles to a point two thousand feet below the line of perpetual snow. On this slope the marks of glacial action were much more conspicuous than at Crater pass. All the projecting points and ridges of the older trap rock were worn down, smoothed off, and cut by deep furrows, which now pointed northeast toward the centre of the mountain mass formed by the Three Sisters.

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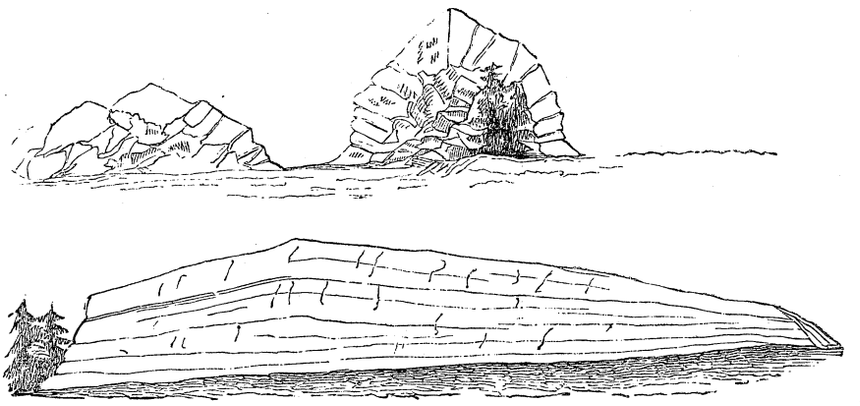
Still later, having crossed the main ridge north of the Three Sisters, we noticed the same phenomena extending down to the altitude of 4,459 feet, where they terminated in a deep cañon, through which a stream flowed into the Willamette valley. This cañon led down from Mount Jefferson, and was joined by another, which came from the Three Sisters. At their point of junction they had a depth of more than a thousand feet. Here, as before, the furrows in the rock pointed to the Three Sisters, bearing from us a little south of east.



TRAP-LEDGES, EXHIBITING MARKS OF GLACIAL ACTION.

We had evidence in these scratched and furrowed rocks of the former existence in these mountains of glaciers, which extended down at least 2,500 feet below the present line of perpetual snow. I suspect, indeed, that they descended much lower, and that they filled the cañons of which I have spoken, which, in the regularity of their outline, and the accurate slopes of their sides seem to have been formed by some such cause. The area over which these marks of glacical action extend is probably very large, including the slopes of the Three Sisters, Mount Jefferson, and all the line of peaks which mark the crest of the chain. And there is little doubt that all this surface was once covered, not simply by lines of ice following the valleys, but by a continuous sheet which, on the west, reached down to the base of the next and lower line of mountains, and that the sides and summits of these subordinate peaks, rising high above the lowest point where I noticed the grooves and scratches, were also capped and covered by masses of ice. These glacial grooves do not seem to have attracted the attention of those who have crossed the Cascade Range further north; but we can hardly suppose that while here the evidences remain of glaciers, so wide, and extending to so low a level, that they could have been produced by the operation of local causes; or that upon more careful examination the traces of their former existence will not be found on the flanks of Mount Hood, the loftiest peak in the chain, of Mount Rainier, and Mount Adams north of the Columbia, and of the many other lower but still elevated summits.

Origin of cañons.—The indications of the existence, in former times, of glaciers extending over large surfaces in the Cascade mountains is closely connected with the formation of the deep cañons, through which the streams which drain these mountains and the plateau of the "Great Basin" beyond uniformly flow. I think we have evidence in the magnitude of the excavation—often in the most resistant material—as compared with their present volume, that the amount of precipitation which formerly supplied them was much greater than now.

The Golden Gate, the Straits of Carquines, the cañon of Pit river—which, following its tortuous course is, for nearly a hundred miles, cut through a succession of walls of volcanic rock—the many cañons of Klamath river, those of the Des Chutes and its tributaries—to which I shall soon have occasion to refer—and the gorge of the Columbia, the most stupendous of all,

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holding, as they do, such peculiar and constant relation to the areas which are drained through them, cannot possibly be regarded as rifts formed by volcanic action in the barriers which they traverse. The conclusion seems irresistible that they have been formed principally, if not entirely, by currents of water, of which the present streams are representatives.

Another of the deeply graven records from which we are attempting to deduce the ancient history of the western coast is found in the great depth of the channels by which these streams terminate in the Pacific. The deep and narrow fiords which mark the northern portion of the western coast, of which those opposite the island of Vancouver, on the coast of Washington Territory, are good examples, have been described by Professor Dana, in his Geology of the Exploring Expedition. The mouth of the Columbia exhibits similar features. For a hundred miles it forms an arm of the sea of great and uniform depth.

The channel of the Golden Gate has a maximum depth of nearly fifty fathoms, being greatest immediately in the line of the axis of the chain through which it is cut, while the bar without and the bay within are silted up to within less than ten fathoms of the surface.

The Straits of Carquines have a maximum depth of eighteen fathoms, and in the line of the range which bounds them an average depth of fourteen.

It is evident that glaciers could now be formed in the Cascade mountains only by a great depression of temperature, and it is perhaps doubtful whether glaciers would now form to the extent indicated by the traces of their former existence, which has been described, even with a depression of temperature so low as to precipitate and congeal all the vapor which floats above them. Without, however, raising that question, we may be at least certain that with the former existence of glaciers in the Cascades, the average temperature was much lower than at present. This must have been dependent upon one of two causes: either a great and radical difference in the climate of the coast without a change of elevation, or, the climate remaining the same, by the elevation of the coast to a general altitude several thousand feet higher than at present.

Of the condition required by the first of these hypotheses we have no other evidence than that of the glaciers themselves, while of the former elevation of the coast, in the sub-ærial excavation of the fiords at the north in the deep channel of the Columbia, and, as it seems to me, in that of the Golden Gate, we have cumulative and conclusive proof. The effect of such an elevation as would be required to cover the slopes and valleys of the Cascades with glaciers, would be exhibited in various ways. The amount of moisture precipitated upon the sides of these mountains would then be much greater than now. Instead of presenting isolated peaks rising above the line of congelation, they would form an unbroken wall, of which the summit, white with perpetual frost, would rob of all its moisture the wind, then as now, blowing over it from the Pacific. This precipitation, though greatest on the western slopes, and forming by its congelation sheets of ice which would reach far down its sides, crowding themselves into the angular valleys which now lead toward the Pacific, would also extend its influence to the eastern slope, fill many of its basins, now dry, with water, give greater volume and efficiency to the streams, and enable them to score so deeply the surfaces of the plateau, and force mountain barriers to reach the ocean, cutting deep channels in its shores where we now find them.

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CHAPTER VI.

GEOLOGY OF THE DES CHUTES BASIN.

COMPOUND NATURE OF THIS BASIN.—ITS SUBDIVISIONS SIMILAR IN STRUCTURE TO THOSE OF PIT AND KLAMATH RIVERS.—TRAP PLATEAUS.—VOLCANIC TUFAS AND INFUSORIAL MARLS.—LOCAL GEOLOGY.—PLATEAU EAST OF THREE SISTERS.—CAÑON OF MPTO-LY-AS RIVER.—MOUNT JEFFERSON.—CONGEALED LAVA STREAM.—CASTLE ROCK.—COLUMNS OF BASALTIC CONGLOMERATE CAPPED WITH BLOCKS OF TRAP.—TUFACEOUS STRATA OF MPTO-LY-AS RIVER.—CAÑON OF PSUC-SEE-QUE CREEK.—PICTURESQUE APPEARANCE OF THE COLORED TUFAS AND CONCRETE.—TRUNKS OF CONIFEROUS TREES IMBEDDED IN TUFA.—COLUMNAR TRAP COVERING THE TUFAS.—WAM-CHUCK RIVER.—HOT SPRINGS.—GELATINOUS SILICA.—METAMORPHOSED TUFAS.—ONYX.—OPAL.—AGATE.—SILICIFIED WOOD.—WAM CHUCK MOUNTAINS.—METAMORPHIC SLATES.—QUARTZ AND CHALCEDONY.—NEE-NEE SPRING.—METAMORPHOSED MARLS.—RIBBAND JASPER.—PLATEAU OF TYSCH PRAIRIE.—TYSCH MOUNTAINS.—VIEW OF MOUNT HOOD.—CAÑON OF DES CHUTES RIVER.—MOUNDS.—HILLS OF INFUSORIAL MARL SOUTH OF THE COLUMBIA.

ALTHOUGH for convenience it may be desirable to group, under the name of the Des Chutes basin, the several distinct areas which are drained by the waters of the Des Chutes river, it should be stated that no such surface exists as would be indicated by its unqualified use. The several divisions which it must include have only in common their geological structure which, in all its essential particulars, they also share with the Klamath and Pit river basins. But while differing little in kind from that of the areas I have mentioned, the geology of the Des Chutes basin exhibits some striking features in the scale on which it is developed. Lying near the base of the chain of great volcanic cones which forms the axis of the Cascade range, immense quantities of erupted material have been thrown over it, which contrast strongly with the modest trap ridges, pumice plains, and fine chalk-like marls of the Klamath basin.

The Des Chutes basin consists of a series of plateaus, having varying elevations from 4,000 to 2,200 feet above the level of the sea, and being separated by subordinate ranges of volcanic mountains, of so low an elevation as scarcely to be noticed when overlooking the general surface from the Cascade mountains. These plateaus are usually covered by a floor of trap, which extends in a smooth sheet from fifty to a hundred and fifty feet in thickness, unbroken, except where crowning the slopes of the profound cañons of the streams which traverse them. These layers of trap are frequently columnar, the columns being perpendicular. Below this stratum we find a series of volcanic marls, tufas, and conglomerates, locally intercalated with which are thin beds of trap.

These tufaceous strata are, in many places, cut by the Des Chutes and its tributaries to the depth of more than a thousand feet without exposing the basis on which they rest. They are usually quite horizontal, from a few lines to twenty feet in thickness, and very accurately stratified. They exhibit great variety of color and texture, some being very fine and chalk-like, in all respects similar to those of Klamath and Pit river basins, while others are composed of fragments of pumice, volcanic sand, and a firmly cemented conglomerate of trap, pumice, scoria, and other erupted rocks. Some are pure white, others pink, orange, blue, brown, or green. The sections made by their exposures have a picturesque and peculiar appearance, of which some idea may be formed from the geological diagrams used in the lecture room.

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The subordinate mountain ranges which divide the Des Chutes basin are usually low, having an altitude rarely greater than 1,000 feet above the level of the plateaus which border them. They are composed of trap or metamorphic slate, sometimes forming groups or clusters of conical hills; at other times continuous chains, of which the trends do not harmonize with each other, nor with those of the mountain systems which border either side of the great area in which they are situated.

LOCAL GEOLOGY.

The plateau forming the eastern base of the group of mountains, of which the Three Sisters are the most prominent peaks, has a nearly uniform altitude of about 4,000 feet, and extends from the base of the Cascades thirty miles eastward, with no considerable interruption. It is here everywhere covered by a thick layer of trap, which is cut through only by the cañon of the Des Chutes, which we did not visit, but of which the dark and perpendicular walls were visible from the summit of the Cascades. Near our depot camp, on Why-chus creek, a rounded hill rises some three hundred feet above this plain, composed of trap, or red and frothy scoria. This hill has the appearance of having been formed by an eruption from below, subsequent to the consolidation of the plain on which it stands. A few miles northwest from this point a detached mountain rises from the plain, more accurately conical in outline than any other I have seen. It is wooded to the summit, though exhibiting many bare surfaces composed of scoria. There can hardly be a question that this is one of the lateral vents of the great volcanic chain which passes but few miles to the westward of it.

East of this conical mountain we crossed a succession of ridges of trap, evidently formed by streams of lava poured down from the Cascade range. Approaching Mount Jefferson, we one morning found our progress suddenly arrested by a cañon 1,950 feet in depth. The southern wall on which we stood was composed of metamorphic slate, dark gray in color, silicious and somewhat crystalline in structure. The opposite side of the cañon was formed by the slope of Mount Jefferson, which rose, almost unbroken, to its summit, far above the line of perpetual snow. On the side of Mount Jefferson was plainly discernible a stream of black and ragged lava, which, issuing from a point near the snow line and following the course of a mountain torrent, had descended nearly to the Mpto-ly-as river. Picking our way down the wall of the cañon which I have described, we found all parts above the talus which covered its base, composed of the same metamorphic slate, very homogeneous in texture, and nowhere exhibiting any intruded minerals. This slate was inclined at a high angle, dipping toward the southeast.

From this point we followed down the Mpto-ly-as river, for nearly twenty miles, along the immediate banks of the stream. The walls of the cañon on either side continued as high as where we struck it till we emerged from the hills which form the eastern base of Mount Jefferson, and came upon the plateau of the Des Chutes. This cañon, where cut through the hills, exposes nothing but volcanic rock, generally dark, vesicular trap, with sometimes volcanic conglomerate. In some places where this last formed the north wall of the cañon, the fragments which it included were of large size, cemented by a tufaceous base which was readily eroded by the action of the weather. The portions of this material which here underlie these larger masses of inclosed trap were protected by them from the erosion which wore away the surrounding rock, and they were left perched on pinnacles sometimes twenty or thirty feet in height, and having a less diameter at the summit than the rock which they sustain.

The cañon, as far as we followed it, seemed to be of uniform character, precipitous walls rising

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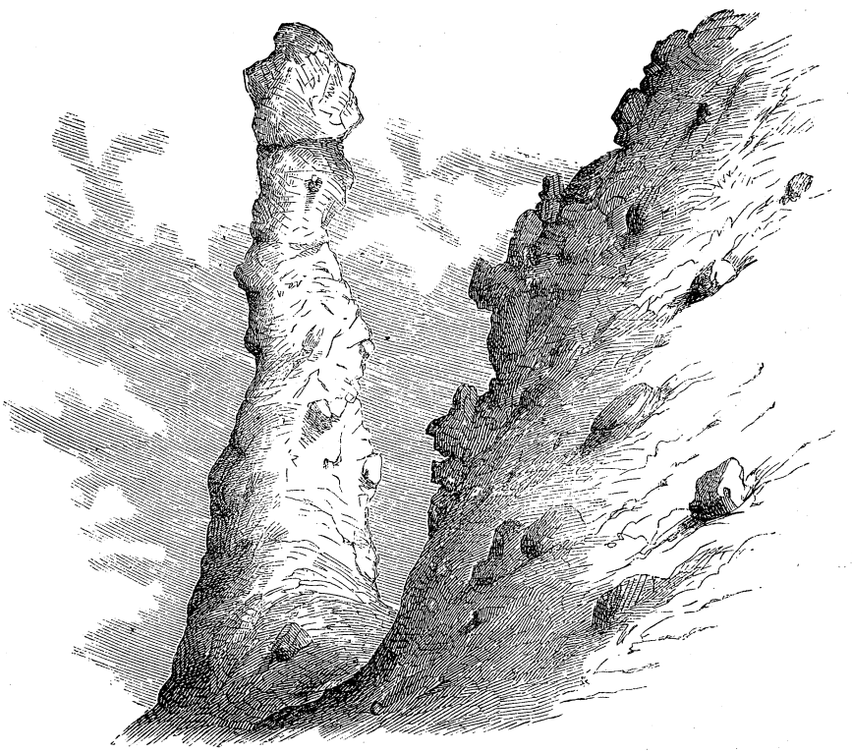
on either side from the immediate vicinity of the stream which flowed at the bottom. It had every appearance of having been excavated from the solid rock which forms its sides. The stream which flows through it is thirty yards in width, three or four feet deep, and very rapid. It is formed by the drainage of Mount Jefferson and the Three Sisters.



CONGLOMERATE COLUMN, MPTO-LY-AS RIVER.

At the point where we left the cañon of Mpto-ly-as river a marked change occurred in the character of the material composing its walls. The precipices, composed of trap and volcanic conglomerate, which with a height of nearly 2,000 feet had enclosed it for twenty miles, were here succeeded by strata of tufas, which formed walls of perhaps 1,200 feet in height, capped by a thick layer of columnar trap. These tufas were nearly horizontally stratified; exhibiting all the varieties which I have described; the different strata varying in thickness from a few inches to twenty feet.

Some of the finer varieties are highly infusorial. The forms which they contain have since been examined by Professor Bailey, who pronounces them indicative of a fresh water origin. We here ascended to the north wall of the cañon, travelling over the plateau to the banks of Psuc-see-que creek, another tributary of the Des Chutes, flowing down from Mount Jefferson. Here we found a similar series of tufas apparently quite undisturbed, their strata horizontal and continuous.

Mingled with these tufas, at this point, are many strata of conglomerate, of which the base resembles closely Roman cement; the inclosed pebbles, usually of small size, and of all varieties of volcanic rock. These beds of concrete being harder than the associated strata, have, in the erosion of the cañon, formed successive steps, frequently thirty or forty feet in width. The detached fragments of these layers of concrete cover and protect pinnacles of the softer stratum

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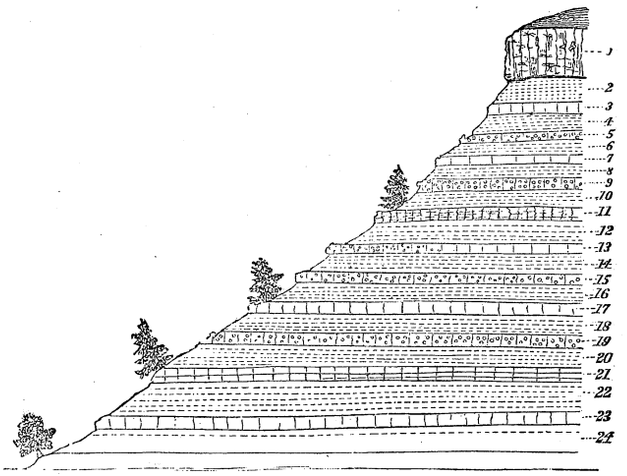
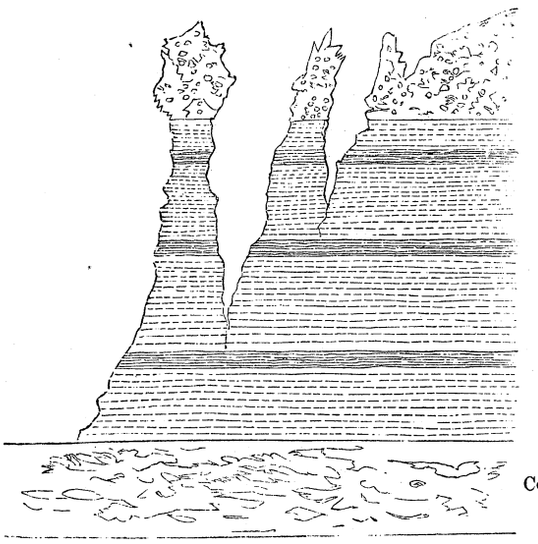
below; a single column often being formed of several successive differently colored layers; the prevailing colors being pink, white, orange, blue, gray, and lilac, and these colors frequently strongly contrasted, producing a very peculiar and pleasing effect.



No. 1, columnar trap.
Nos. 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, soft tufas, and infusorial marls.
Nos. 3, 7, 13, 17, 21, 23, harder tufas.
Nos. 5, 8, 15, 19, concrete.
No. 11, trap.

SECTION OF BANK OF PSUC-SEE-QUE CREEK.

Near the base of the series was a stratum of three feet in thickness, composed for the most part of brilliant white felspathic pumice, so soft as to be easily crumbled in the fingers. This pumice was in somewhat rounded masses, averaging less than an inch in diameter, and



COLORED TUFAS, PSUC-SEE-QUE CREEK.

cemented by a fine lilac colored clay. The general aspect of this layer was that of marbled paper, the spots being pure white and the interstices lilac. A line of dark carbonaceous matter, less than a quarter of an inch in thickness, marked the line of separation between this stratum and another of nearly the same thickness, which was blue in color, having the texture of soft pulverulent coarsish sandstone. The under surface of this layer was pierced in every direction by holes as large as straws, left by the decaying branches of some small plant which had apparently grown from the carbonaceous surface below. The appearance presented by these impressions of

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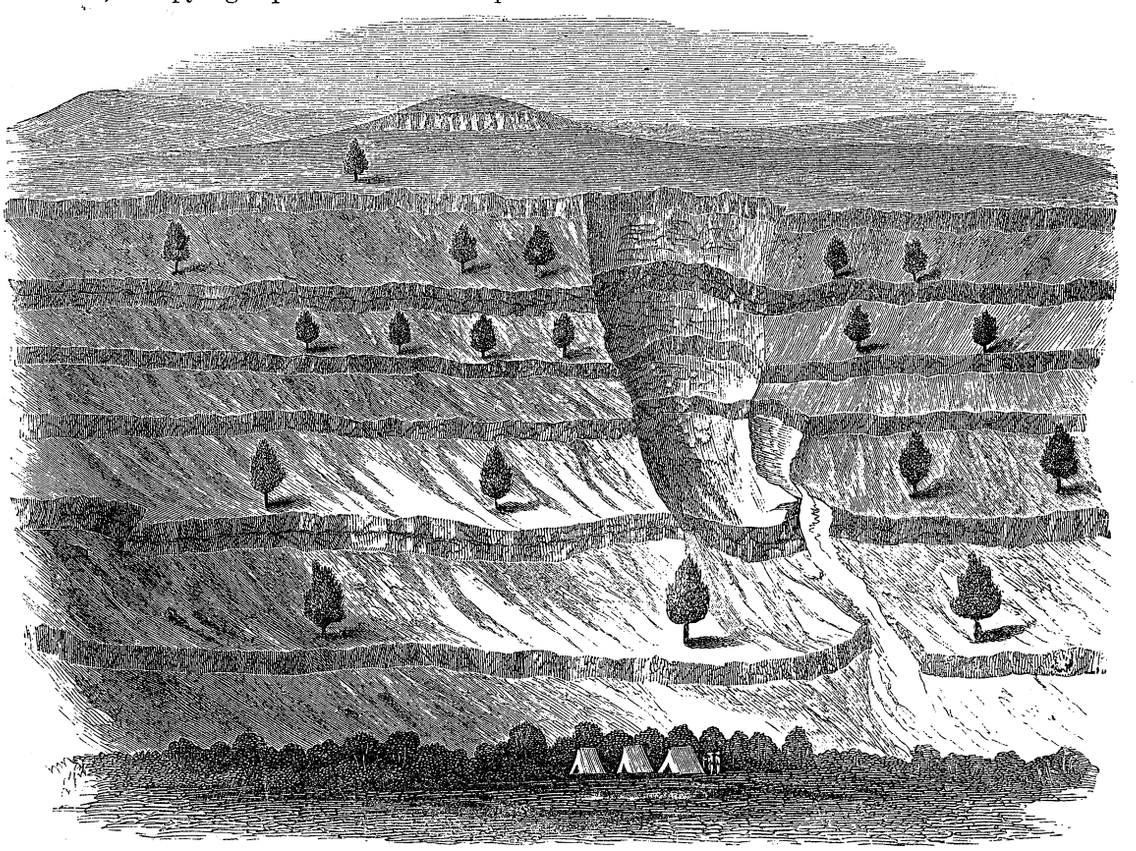
plants led me to suppose that during the interval between the deposition of the lower and upper of these layers a growth of vegetation had covered the lower stratum, which became enveloped in the sediment which formed the upper. The specimens which I obtained of these vegetable impressions did not permit me to determine the class to which they belonged. The branches are opposite and alternate, and the plant must have somewhat resembled the *salicornia* which now grows on our salt marshes. It is possible, too, that these stems of plants may have been transported and deposited at the bottom of the water; but the regularity of their arrangement, and the carbonaceous matter below, indicated to my mind that they had grown where they were found.

Two or three hundred feet higher up in this series I found the trunks of large coniferous trees, and stems and roots of small plants imbedded in strata somewhat similar to those which I have described; but in these cases the vegetable matter had not been fossilized, and resembled decayed wood; the appearance of the trunk set with branches, of which the extremities were broken off, the roots still attached, gave the impression that they had not been transported to any great distance from where they grew. In general form and mode of branching they closely resembled the trees of cedar now growing scattered over the declivities of the cañon.

The succession from the bottom of the cañon to the general level of the plateau, together with these, includes a layer of trap, which forms a horizontal stratum twenty or thirty feet in thickness, occupying a place nearer the top than the bottom of the section.



NORTH BANK OF PSUC-SEE-QUE CREEK.

On the banks of Mpto-ly-as river, in one locality, was a succession of seven of these layers of trap, as perfectly as the materials with which they were associated, and on the slope of the

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cañon exhibiting the typical form of trap stairs. Crossing to Chit-tike creek, the same formation reappears, apparently undisturbed; the cañons of several confluent streams flowing from Mount Jefferson having here cut the plateau into a series of narrow ridges, perhaps a thousand feet in height, crowned with a layer of trap, which closely resembles a wall of artificial masonry, built on an immense artificial embankment.

The east wall of the cañon of the Des Chutes river at this point consists of a layer of trap a hundred feet in thickness, composed of perpendicular columns, from the base of which it slopes away to the water's edge. The course of the stream, marked with geometrical precision by the lines and angles of the stratum of trap stretching off for many miles in perspective, vividly recalled the cyclopean architecture which gives so impressive a character to Martin's paintings.

On going over to the valley of Wam Chuck river, still another tributary of the Des Chutes from the Cascades, we found a marked change had taken place in the stratified tufas, which are so characteristic of the geology of all this region.

Hot Springs.—At different points along the valley of Wam Chuck river, hot springs issue from the base of the cliffs which bound it. The number of these springs is large, and two or three of them are quite copious. They issue from fissures in the rock, the water flowing from them collecting in basins of several feet in diameter, thence flowing into the Wam Chuck river, and giving it its name. The temperature of two of these springs was respectively 143° and 145°. The water holds large quantities of silica in solution, but has a bland and pleasant taste, and, when cooled and drank, has, apparently, no medicinal effect. The quantity of silica is, however, very large; the basins in which the water collects containing floating masses of gelatinous silica, of which the surfaces are tinged with a green color, which I have supposed was derived from silicate of iron. The sides of these basins, and of the streams flowing from them, are encrusted with a white frothy silicious deposit, which also invests whatever stones, sticks, or other foreign substances project from the surface of the water.

Metamorphosed Tufas.—The cliffs which border Wam Chuck river, in the vicinity of the warm springs, are apparently composed of the same or a similar series of volcanic tufas and marls with those described as forming the banks of Mpto-ly-as river, Psuc-see-que and Chit-tike creeks, but here so changed as hardly to be recognized at first sight. They are traversed by a thousand cracks and fissures, from which the steam or water of the hot springs emanate, by which the aspect of the rock has been made to resemble that of serpentine or some light colored volcanic or metamorphic rock which has suffered complete fusion. Upon closer examination, however, many of the varieties of tufaceous rock exposed in the localities referred to above may be here recognized, but presenting such changes of physical character and composition as would deceive the most practised observer, until he had obtained a series which exhibited all the successive grades of metamorphosis. The white, chalk-like, infusorial marls are, by the action of these hot silicious springs, first rendered harder and more dense without marked change of color, subsequently becoming still more consolidated; the extreme form of metamorphism of this variety being a jasper, colored red or green by the silicate or oxide of iron, closely resembling the porcelain jaspers of Germany.

The coarser tufas, such as that described as occuring on Psuc-see-que creek, composed of lumps of fine felspathic pumice, resembling kaolin, cemented by a fine sediment, exhibit more distinct and interesting grades of change. The cement is first consolidated—sometimes remaining bluish-white, sometimes tinged with green—the balls of cotton-like pumice being scarcely changed; second, the cement has become hard and almost crystaline, somewhat resembling

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burrstone; the spaces occupied by the pumice being empty, or containing a small flock of light-reddish matter, the remainder having been dissolved and carried off, or chemically combined. The cavities which the mineral in this state exhibit are angular, their walls having a radiated and crystaline structure, apparently produced by an effort of the particles composing them to assume a spherical form with a radiated arrangement. Not unfrequently a small, hollow, or solid sphere is formed on all or several of the walls of the cavity. The third stage of metamorphosis exhibits these cavities filled with onyx or opal—more rarely with agate—the rock having assumed a peculiar concretionary structure. The onyx consists of bands of red, white, green, or translucent silica, forming specimens of great beauty.

These layers would seem to have been deposited parallel with the horizon, as the bands of color in the onyx, filling different cavities of the same mass, are accurately parallel. In some cases the cavities are but partially filled, several bands stretching across from side to side, with open spaces between them.

The opalescent silica exhibited considerable variety, some being milk white and opaque, apparently retaining a considerable portion of felspathic material which originally filled the cavity. Other specimens were more transparent, sometimes exhibiting the beautiful reflections of precious opal. I was able to satisfy myself on the spot, as well as obtain a series of specimens, which show that all these changes, and those of other varieties, which it is not necessary to enumerate, followed the action of hot water containing large quantities of silica in solution upon the porous and permeable structure of tufas and marls.

Metamorphosis so complete, and due to such a cause, would not be without interest, though limited to small quantities of material. We had here evidences, however, that the metamorphosis of these tufas extended over a large area, for we found the same or similar changes indicated in the stratified deposits at points on our route more than ten miles distant. Where trap rock had been exposed to the action of these springs, it had, to a great degree, been converted into a blood-red pulverulent earth.

Silicified wood is very abundant in the Hot Spring valley, and has doubtless been mineralized by the action of the hot silicious water. I suspect it will be found that the profusion of silicified wood, which has been so frequently noticed in different parts of the area lying between the Cascade range and the Rocky mountains, is traceable to the same cause.

Fossil wood was also given me, collected near the hot springs at the head of Pit river, by a gentleman whom we saw at Fort Reading, and it is known to abound in those portions of the area called the Great Basin, in New Mexico and northward, which are most marked by volcanic phenomena, and by the occurrence of hot springs.

At the Cascades of the Columbia, fossil wood has attracted the attention of every traveller who has passed. There, too, I think we can connect its occurrence with recent volcanic eruptions.

The thermal springs of the Wam Chuck valley are probably of ancient date, and in their origin are doubtless connected with the Wam Chuck mountains, about the base of which they rise.

WAM CHUCK MOUNTAINS.

These mountains form a group of rounded summits, rising abruptly from the plain which encircles them on the east, west, and south sides. They are composed of metamorphic slates and trap, exhibiting but little variety of structure or material. They have the appearance of greater age than many of the volcanic hills and ridges which we have passed—an appearance

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due to the regularity of their outlines, as well as to the entire absence of recent volcanic rock. The slates which for the most part compose them are alumino-silicious, very hard and highly metamorphosed, exhibiting the same general characters with those which form so prominent a feature in the geology of the Cascade mountains west of its principal axis. They are divided by deep, narrow ravines, and their slopes are long and steep, generally unbroken by any projecting crag or perpendicular wall. The surface of these mountains is in many places strewed with geodes and crystals of quartz, or masses of chalcedony, which have apparently filled cavities in the rocks composing them.

At Nee-nee Springs, several miles north of the Wam Chuck valley, stratified tufas—here somewhat disturbed and broken—exhibit varieties of metamorphism not before noticed. What was formerly one of the finer marls is here converted into a kind of fine-grained sandstone, marked with ribbon-like lines of red and white. These seem to be the lines of deposition, and indicate a periodical recurrence of the effects produced by two sets of causes. The red lines, which are perfectly distinct—sometimes not thicker than a sheet of paper; more frequently combining to form bands a quarter of an inch in width—alternate with lines of white of about the same width and of somewhat coarser texture. Small masses of scoria are disseminated through the rock, and over these the lines of deposition are flexed, showing that the different bands were formed by alternating layers of sediment—the flexures of the lines of deposition over a foreign body indicating, even in a hand specimen, which was the superior and which the inferior surface. The general parallelism, and the continuity of the most delicate lines of color, show that these sediments were deposited in tranquil water—the bands of red indicating the periods of most perfect quiet, when the finer materials, including a larger quantity of iron, sank to the bottom. I have supposed it possible that the presence of iron in the red bands was due to infusoria. If this material were carried through the same stages of metamorphosis as much we have seen, it would form beautiful ribbon jasper. More perfect imitations of the ribbon jasper of Germany and Egypt were, however, found at the Hot Springs, where a jaspery rock was marked by bands of red and green.

TYSCH PRAIRIE.

North of the Wam Chuck mountains we came down on to Tysch prairie, which forms a plateau precisely similar, in all its general features, to those we had previously traversed, but lying at a lower level, having an altitude of but 2,200 feet above the sea. Mount Hood rises from its western border, presenting an appearance remarkably imposing and beautiful, well represented in plate No. IX, illustrating the general report of Lieutenant Abbot. From the base of the Cascades it stretches eastward for thirty miles or more, forming a nearly level plain, cut by the deep cañons of Tysch creek and the Des Chutes. This plain is everywhere underlaid by a stratum of trap, beneath which is a series of stratified tufas.

TYSCH MOUNTAINS.

The mountains which bound Tysch prairie on the north rise to an altitude of about 2,500 feet above it. Their outlines are all rounded, and they are composed principally of compact trap, not of recent date; and of which all the rough and ragged surfaces have been worn away by the action of the elements.

Like Wam Chuck mountains, rising abruptly from the plateau which surrounds them, they have a peculiar insular appearance. Like the Wam Chuck mountains, too, their slopes toward

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the north are long and gentle—toward the south, short and steep. The view from their summits is exceedingly picturesque and peculiar. Except on the slopes of the Cascades, no forests are visible. Lines of trees follow the streams which come down from the mountains far out into the prairies, and a few pines and cedars crown the summits of the hills lying southward. With these exceptions, the whole country is covered by a sparse growth of grass, now everywhere dry, tinging the landscape with a universal monotonous brown.

The Cascades, from this point, exhibit a scene of unusual grandeur. Mount Hood, directly west, rises to a height, variously estimated, at from 15,000 to 18,000 feet; its summit not unfrequently enveloped in clouds, and, in a clear atmosphere, giving off steam or smoke. Mount Jefferson distinctly visible in the west, and Mount Rainier and Mount Adams, snow peaks north of the Columbia, in the northwest. The cañon of the Des Chutes appears like a deep, dark gorge, traversing the plateau of which I have spoken.

The region lying between the Tysch mountains and the Columbia is occupied by a series of rounded grass-covered hills, having an altitude above the valleys which divide them of several hundred feet; precisely resembling, in appearance, the sandstone hills about Benicia, in California. They are composed of white, frequently infusorial, marls, belonging to the same series with those which cover so large a surface in other parts of the Des Chutes basin. Here, as elsewhere, the infusorial forms which they contain are of fresh water origin.

Mounds.—Every day while traversing the Des Chutes basin we noticed upon surfaces unoccupied by trees numbers of low and rounded mounds, apparently formed by causes not now in operation. As we progressed toward the north, they became more numerous and of larger size. In the vicinity of the Dalles they form a very marked feature in the scenery; in many places covering the prairies and hillsides so completely that their margins are almost in contact. They have here an altitude of from three to five feet, and a diameter of from twenty to fifty. Although I have examined them with great care, I have been unable to arrive at any satisfactory conclusion in respect to their origin. They occupy equally the hillsides and the levels, and exhibit no traces of stratification, nor is there anything in their structure which afforded me any clue to the cause or manner of their formation. I have seen in California mounds not very unlike, but of less magnitude, formed by burrowing squirrels, but it seems impossible that this cause could have here produced them.

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CHAPTER VII.

GEOLOGY OF THE COUNTRY BORDERING THE COLUMBIA RIVER.

REGION EAST OF THE CASCADE MOUNTAINS.—GENERAL FEATURES APPARENTLY SIMILAR TO THOSE OF DES CHUTES BASIN.—LOCAL GEOLOGY.—DALLES OF THE COLUMBIA.—SEDIMENTARY INFUSORIAL DEPOSITS.—THEIR FRESH WATER ORIGIN.—THEIR AGE.—THE CAÑON OF THE COLUMBIA.—GENERAL FEATURES.—HOW FORMED.—LOCAL GEOLOGY.—HORIZONTAL STRATA OF TRAP.—SUBMERGED FOREST.—CASCADES FORMED BY SLIDE FROM MOUNTAINS.—CONGLOMERATE.—SILICIFIED WOOD.—TERTIARY STRATA BELOW CASCADES.—COUNTRY BORDERING THE LOWER COLUMBIA.—GENERAL FEATURES.—WILLAMETTE VALLEY.—ITS RESEMBLANCE TO THE CALIFORNIAN VALLEY.—LOCAL GEOLOGY.—WESTERN SLOPE OF THE CASCADE RANGE.—CAÑON OF MCKENZIE'S FORK.—MARKS OF GLACIAL ACTION ON MOUNT HOOD.—TRAP, SCORIA, ASHES, ETC., FROM MOUNT HOOD.—TRAP AND SANDSTONES OF WILLAMETTE VALLEY.—EROSION OF SANDSTONES.—LIGNITES NEAR ST. HELENS.—TERRACES.—COAST MOUNTAINS.—SANDSTONES AND SHALES OF ASTORIA.—FOSSILS.—AGE OF THE DEPOSIT.—PORT ORFORD.—TERTIARY SANDSTONES, TRAP.—GOLD.

GENERAL FEATURES.

THE entire region drained by the tributaries of the upper Columbia has apparently so many features common to all its parts, in its geological structure, its climate, its indigenous plants and animals, that it can only be properly studied as a whole. So viewed, it would furnish an interesting subject of investigation in tracing the connexion and community of character of its parts, and deducing from the common phenomena which they exhibit the common causes which have produced them.

The Des Chutes basin and the banks of the Columbia in the immediate vicinity of the Dalles are the only portions of this area which I visited, and I should not be warranted in deducing the structure of the whole from so small a part. From published and oral descriptions, however, of the country traversed by the upper Columbia, as well as from specimens received from different localities, I am led to believe that the Des Chutes basin may be considered as a type of the greater part of it; and that what has been said of the origin of the geological structure exhibited by that portion of the basin of the Columbia which I saw, is equally applicable to at least that part of it which lies north of the Columbia, and immediately east of the Cascade range.

These mountains have, as we learn from the graphic descriptions of Mr. George Gibbs, (U. S. P. R. R. Explor. & Surveys, vol. II,) much the same character north of the Columbia as in Oregon. Volcanic peaks crown the crest of the chain, which have deluged the country with floods of lava, and thrown out showers of ashes, from which beds of tufa have been formed similar to those of the Des Chutes basin. Specimens from the banks of the Yakima and upper Columbia, which I have received, are undistinguishable from those collected on Psuc-see-que creek. Basin-like areas, enclosed by walls, now cut through by the draining streams, have been described in varying language by all who have visited this region.

The Columbia drains many basins and traverses many cañons before it reaches the great gorge in which it flows through the mountains; and it came to the herculean task of excavating that channel, no novice in the art of stone-cutting, but skilled by a training begun with its birth, in the thousand mountain streamlets which combine to form it.

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LOCAL GEOLOGY.

The trough of the Columbia at the Dalles is similar, in all its general features, to the cañons of the streams which traverse the Des Chutes basin. The banks which bound it are less abrupt and further removed from the channel; but this difference is, doubtless, due to the absence of the thick bed of overlying trap which protects the softer marls from erosion, and forms the precipitous walls which enclose the Des Chutes. Layers of trap occur, however, at several points in the slopes of its banks, which are very noticeable to any one descending to the stream, but they are of less thickness and less continuous than those of which I have spoken.

The Dalles of the Columbia are formed by one of these beds of trap, through which the stream cuts in deep and narrow channels, which have received the name of Dalles. Directly opposite the village, the north bank of the river presents the mural edge of a layer of trap which is partially columnar, and continuous for some miles. Although so much modified by the erosion to which I have referred, the banks of the Columbia, at the entrance to the great cañon which traverses the Cascades, are formed of sedimentary deposits, which were once continuous over all the area now occupied by the valley through which it flows; and, although these strata have been somewhat disturbed, I think we have conclusive evidence that they have been eroded, by the deepening of the bed of the stream, to a point two thousand feet below their upper surface. The area about the entrance of the cañon of the Columbia corresponds in every essential particular to those which are drained through the several cañons of Pit river, the Klamath, and the Des Chutes. Whatever has been said, therefore, in reference to those areas, the sedimentary deposits which occupy them, and the cañons formed by their draining streams, is equally applicable to the basin of the Columbia; and if its structure has not at once suggested its history to those who have examined it, it is doubtless because, from its magnitude, it could hardly be viewed as a whole, and it was necessary to come to its study through similar but smaller basins, which could, with all their relations, be taken in at one view.

In all these basins the sedimentary deposits, so accurately stratified over such large areas, prove the presence and agency of water of considerable depth. The deeply cut cañons through which they are drained must have been worn by streams which commenced their work of erosion many hundred, sometimes two or three thousand, feet above their present beds. The nature of the sediments deposited by this water proves that it was fresh. Among the great number of specimens of deposits known or suspected to be infusorial, collected in Oregon or California, and sent to Prof. J. W. Bailey for examination, were some from Monterey, from Shoalwater bay in Washington Territory, and several other points on the coast. With these were representatives of the infusorial marls of the different basins of Pit river, the Klamath, the Des Chutes, and the Columbia.

A short time previous to the death of this eminent microscopist, he indicated to me the results of his first examination of these specimens; and, although the localities were but imperfectly known to him, I was much interested to observe that, while the infusorial deposits of Monterey were marked as containing marine forms, and others on or near the coast as containing mingled marine and fluviatile forms, every specimen collected east of the Cascades, or Sierra Nevada, was said to contain only "fresh water *Diatomaceæ*." It is a little remarkable that, in these great accumulations of stratified sediments, many of them fine, and indicating the tranquillity of the water in which they were deposited, I was able to discover no other fossils than the infusoria referred to; nor did I find any other organisms but the imperfectly preserved plants of Psuc-see-que creek; the only intelligible vegetable remains being trunks of coniferous trees. From

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these facts we must infer that the fauna and flora of that period were exceedingly meagre; a state of things which we might expect with the arctic temperature which should form glaciers in the Cascades; the drainage from which supplied these basins.

The question of the age of the tufas of the basins east of the Cascade mountains is not without its interest in this connexion, for, if they are of ancient date, it would be impossible to associate them with the modern and superficial phenomena of glaciers. We have every evidence however, that, geologically speaking, they are very recent; the unmineralized vegetable matter which they contain proving this conclusively. They have evidently been formed of materials thrown out and washed down from the volcanic peaks which crown the summit of the Cascade mountains, and which have been in vigorous action within a few hundred years. Similar deposits in the valleys west of the Sierra Nevada belong to a period subsequent to the tertiary, as they contain the remains of the mammoth and mastodon, and are not older than the drift.

On the plateaus of the Des Chutes and Klamath basins I was never able to detect the least evidence of the action of drift currents. On the contrary, it was perfectly apparent that the trap plateaus, the volcanic ridges, and the rough and ragged lava plains, had never been submerged, but presented surfaces in all respects similar to those first formed, except where covered by a soil derived from the disintegration of the rock, through the agency of the atmosphere or vegetation. I may say, in conclusion, that the glaciers of the Cascade mountains, stratified deposits of great thickness, exhibiting nearly an entire absence of fossils, and not older than the drift, large lakes once existing where now are only arid plains, and cañons cut through mountain walls, offer an interesting parallel with the stupendous phenomena, and evidences of change elsewhere furnished by the drift, and afford, at least, presumptive evidence of synchronism.

THE CAÑON OF THE COLUMBIA.

GENERAL FEATURES.

On any other supposition than that the gorge of the Columbia has been cut by the stream now flowing through it, it becomes a matter of no little difficulty to account for its existence. To the theory more commonly adopted, that it is a rift formed by volcanic forces, many objections at once suggest themselves.

Fissures caused by earthquakes or volcanic action have never been known to assume such a form or direction. We should expect to find them, if at all in that region, radiating from some one of the great foci of volcanic forces; Mount Hood, Mount Jefferson, Mount Adams, or Mount Baker; while, on the contrary, we find this gorge traversing the entire, though compound chain, and afterward the Coast mountains, with a line of bearing which shows that the forces which formed it did not centre in the peaks I have mentioned, nor any other of the range.

We should also expect, if such was its origin, that other and similar fissures would be not uncommon, or at least unknown in the mountain chain which it traverses; but it is a singular fact that, throughout the entire breadth of Washington and Oregon Territories, from the British line to the boundaries of California, the Cascade mountains extend in a wall whose continuity is broken only by this single gorge.

The lowest of its passes (Abbot's new pass) has an altitude of not less than 4,400 feet. In winter, the chain cannot be crossed, and in summer the obstacles which it presents are such that loaded mules are taken over with difficulty; and yet through this barrier the Columbia flows nearly at the sea level.

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The structure of the cañon of Pit river, the relations which all the cañons I have described sustain to the basins drained through them, the sediments accumulated to such a depth above the beds of the present draining streams, &c., aside from the want of another adequate cause, has led me to consider the gorge of the Columbia as formed, entirely or in part, by water. We may obtain further evidence in the case by studying its

LOCAL GEOLOGY.

Within a few miles of the Dalles the river enters the "gorge of the Columbia," and from that time to its exit, fifty miles below, the view of the traveller is bounded on either side by high mountains, which rise with precipitous walls immediately from the water's edge. Except in a few rare instances, where streams come down from the mountains, on either side, there is no level land between the base of the cliffs and the river. This gorge has everywhere the appearance of having been cut through by the stream which now traverses it. In many places there are perpendicular walls of trap rock many hundred feet in height, composed of different strata, formed by distinct overflows, of which the cut edges are now exposed. These layers of trap are often horizontal, and apparently continuous for miles. They frequently, too, exhibit a columnar structure, the columns being perpendicular, and evidently have been subject to no disturbance since their formation. Near the Cascades, however, there are evidences of very recent volcanic action. The layers of trap are more or less disturbed, and the mountains, particularly on the north side, exhibit large surfaces covered with blood-red scoria.

Submerged forest.—The river, from the Dalles to the Cascades, is very deep, has an imperceptible current, and has rather the appearance of an elongated lake than of a flowing stream. At intervals, over the entire distance from the point where we entered the mountains to the Cascades, the river is bordered on either side by the erect, but partially decayed, stumps of trees, which project in considerable numbers above the surface of the water. This has been termed the sunken forest, and has been generally attributed to slides from the sides of the mountains, which have carried down into the bed of the stream the standing trees. This phenomenon is, however, dependent on a different cause. As I have mentioned, the vicinity of the falls has been the scene of recent volcanic action. A consequence of this action has been the precipitation of a portion of the wall bordering the stream into its bed. This impediment acting as a dam, has raised the level of the water above the Cascades, giving to the stream its lake-like appearance, and submerging a portion of the trees which lined its banks. Of these trees, killed by the water, the stumps of many are still standing, and by their degree of preservation attest the modern date of the catastrophe. On examination, I found these stumps to be the remains of trees of the Douglass spruce, which still forms the forests covering the slopes of these mountains.

Cascades.—At the Cascades the river is deflected against the southern wall of its cañon, and, in a succession of rapids, falls sixty feet in three miles.

The material which composes the dam in the river at the Cascades is a kind of conglomerate, made up of fragments of trap rock, mingled with earth and sand. This is, in many places, penetrated by threads of silica, which has often filled cavities and formed masses of agate and chalcedony. In this conglomerate are imbedded many trunks of trees, which are sometimes silicified, in other cases merely carbonized, and occasionally the same trunk exhibits both forms of preservation. Of these silicified trunks there are some of large size, which so much resemble recent wood as completely to deceive the eye. In many of them the structure

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of the wood is very well preserved, and, upon microscopic examination, seems identical with that of the Douglass spruce now growing on the same surface.

Below the Cascades, and on the western skirts of the Cascade mountains, the river is in some places bordered by tertiary strata, which I had no opportunity of examining. The hills and mountains adjacent to the stream below seem to be still, as above, composed of trap and metamorphic slates.

THE COUNTRY BORDERING THE LOWER COLUMBIA.

GENERAL FEATURES.

The parallelism between the valleys traversed by the Sacramento and the San Joaquin and that traversed by the Willamette and Cowlitz has been before alluded to. This parallelism is much more complete than might be inferred simply from the general similarity of figure. If, as seems inevitable from the facts that have been stated, the Sierra Nevada and Cascade range form portions of the same mountain chain, the two great valleys—those of Oregon and California—are bounded on the east by the same wall. The Coast mountains of Oregon, as has also been stated, exhibit a remarkable similarity in their physical features and in geological structure with those of California, and we have every reason to believe that they form a continuation of the same chain. The sandstones and shales, which, with trap, are the only rocks exposed on the lower Columbia, and that portion of the Willamette valley which I examined, contain but few fossils, resembling in that respect, as well as in their lithological features, the sandstones and shales so characteristic of the coast ranges in the vicinity of San Francisco. Near the mouth of the Cowlitz they contain beds of lignite of greater thickness than in any part of California which I visited; and the sandstones near Astoria have yielded a large number of fossils, which have been described by Mr. Conrad in the geology of the exploring expedition, and pronounced by him to be of Miocene age.

LOCAL GEOLOGY.

WESTERN SLOPE OF CASCADE MOUNTAINS.

While I descended the Columbia, two detachments of our party crossed the Cascades to the Willamette valley. Of these one, under the command of Lieutenant Williamson, passed south of the Three Sisters, crossing the summit something more than 150 miles south of the Columbia, following down the middle fork of the Willamette to its junction with the main stream. The other, under command of Lieutenant Abbot, crossed by a pass discovered by him just south of Mount Hood. From the gentlemen connected with these parties I received much valuable information, and specimens illustrative of the geology of that portion of the range which they traversed. From Lieutenant Williamson I learned that the entire mass of the chain at the point where he crossed it is composed of the same trappean and metamorphic rocks that have been noticed as constituting the geology of the region about the Three Sisters. No stratified rocks were met with before reaching the lower portions of Willamette valley, where the tertiary sandstones are largely developed, and by erosion have formed hills several hundred feet in altitude. These sandstones, with masses of vesicular trap, were the only rocks which he noticed in traversing the valley.

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It will be remembered that, when speaking of the glacical grooves on the western declivity of the Three Sisters, reference was made to two deep cañons, one leading down from Mount Jefferson, the other from the Three Sisters, which combined to form a profound gorge leading westward, through which a stream flowed, supposed to be a tributary of the Willamette. This stream proved to be McKenzie's fork, and, when crossing it, near its junction with the Willamette, Lieut. W. learned that upon one occasion, and only one, its course had been followed from its source.

Three hunters, having descended to the Willamette in its bed, reported that, throughout its entire length, the cañon of which I have spoken preserves the character which it exhibits at its eastern termination—a deep and narrow gorge, bounded by nearly precipitous walls, from which there was no exit but at the extremities. Its inhospitable nature may be inferred from the fact that one of these hunters died from the hardships he encountered in traversing it, and the others suffered so severely that they never cared to repeat the experiment.

This would seem to have been the channel through which the drainage from the glaciers had found a passage to the ocean; and it is not improbable even, from its peculiar angular character, that ice occupied some portion of its length. From Mr. Anderson, who accompanied Lieut. Abbot, I learned that the draining valleys leading from Mount Hood have the same angular character, and there, as on the slopes of the Three Sisters and Mount Jefferson, the exposed surfaces of the rocks, in many places, exhibit marks of glacial action.

The minerals brought from Mount Hood are all volcanic, trap, volcanic conglomerate, scoria, and ashes. The ashes are white and fine, and closely resemble the marls and tufas of the Des Chutes and Klamath basins. They had probably been quite recently thrown out from Mount Hood; showers of ashes having been discharged from this mountain several times since Oregon has been occupied by the whites. From Mr. Dryer, of Portland, who attempted to ascend Mount Hood in 1854, I learned that steam and heated gases were escaping from its summit, in many places, at the time of his visit.

WILLAMETTE VALLEY.

I was able to examine but a small portion of the Willamette valley in person, as I ascended the river only twenty miles from its mouth. The only rock which I saw was the tertiary sandstone to which I have alluded, and dark vesicular trap. The sandstone appears in the bed and banks of the Willamette at several points below Oregon City. The rock over which the river pours at the falls is trap, as are the hills in the vicinity. From the detailed account of the geological structure of the valley above this point, given by Prof. Dana in his geology of the exploring expedition, it appears that the hills bordering the alluvial plain, as far south as the Calapooya mountains, are composed of one or the other of the two rocks I have mentioned. He represents the sandstones as being not only disturbed, but greatly eroded, as at the points examined by Lieut. Williamson. This is not an uninteresting fact, when taken in connexion with the evidences of great erosive action which I have cited, and which seem to be connected with the existence of glaciers, and may be, in a degree, dependant on the same cause. The sandstones of the Willamette valley contain no fossils at the localities where I examined them, but they exhibit all the lithological characters of the San Francisco group. In some places they are highly argillaceous, and better deserve the name of shales than sandstones, and not unfrequently contain laminæ of gypsum. Near St. Helens, a bed of lignite has been discovered, which at one time was supposed to have a high commercial value, but which ha

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proved to be nearly worthless as fuel. It occurs in argillaceous sandstone, apparently forming a portion of this series.

Terraces.—At Vancouver the banks of the Columbia are distinctly terraced. The alluvial bottom lands had an elevation of twenty feet above the surface of the water during the month which I spent there; but at certain seasons, as evinced by the collected drift wood, are liable to overflow. Above this level the terrace upon which the fort stands rises to a height which I estimated at forty feet. This terrace is found bordering not only the Columbia, but also the Willamette, and is the one upon which the town of Portland is built. From any elevated point where a view can be obtained over the dense forest which covers the country bordering the Willamette river near its mouth this terrace is seen to be distinctly marked by the summits of the trees, and may thus be traced for miles. The soil of the alluvial lands bordering the streams is fine, dark, and very fertile; that of the upper terrace is frequently gravelly and less productive.

COAST MOUNTAINS.

The Columbia, from the mouth of the Willamette to the ocean, forms rather an arm of the sea than a river channel. It is broad, in many places deep, and on either side bordered by marshes and swamps, which have the appearance of having been depressed below the level which they once occupied. Its bed is nowhere formed of rock, but seems like a trough, broadly and deeply excavated, and subsequently silted up by the sediment, which an arrested current no longer held in suspension.

The mountains which rise on either side form a broad belt, marked by no summit of great elevation, and everywhere covered with a dense evergreen forest. I had little opportunity of examining their geological structure, but noticed at various points masses of trap, and along the river, near its mouth, at a lower elevation, beds of tertiary sandstones and shales. Near Astoria these strata are fully exposed, but, in the brief time that I remained there, I was able to do little more than note the remarkable similarity, in lithological character, which they exhibit to those of San Francisco and San Pablo bay. Many species of fossils were, however, collected from the same series in this vicinity by Professor Dana, and have been described by Mr. Conrad in the geology of the exploring expedition. They have been regarded by him as of Miocene age, though containing no recent species, nor any previously described, from tertiary rocks in other localities. These fossils are chiefly molluscous, with bones of cetaceans and fishes. They are usually found forming the nuclei of calcareous concretions.

PORT ORFORD.

From the mouth of the Columbia to this point the coast presents a bold, irregular outline, with scarcely any level land along the shore. It is everywhere covered with a dense forest, and that portion north of the Umpqua river has been but rarely traversed by explorers. Of its geological structure almost nothing is known, except of the small portion visited by Professor Dana, in his excursion to the Saddle mountain, near Astoria. This mountain, as might be inferred from its outline, is volcanic, and has been in action at a comparatively late period.

The geology of the vicinity of Port Orford is similar, in all its general features, to that of Astoria. The high lands in the vicinity, as well as the bold and rocky points on the shore, are composed of trap rock. Beds of sandstone line the coast north of Port Orford, closely resembling the sandstones and shales of Astoria, and probably belonging to the same series.

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They abound in lignite and fossil wood, and are doubtless of the same age. They are also, probably, continuous with the sandstones of Coose bay, which contain the beds of lignite now worked as coal.

The geology of the vicinity of Port Orford is interesting, from the fact that gold is obtained there by washing the beach sand. The source from which it is derived is not very apparent, but it has, probably, come from the decomposition of the auriferous slates which compose a portion of the mountains lying back from the coast, and extending from the Coquille river southwesterly to Mount Shasta and the head of the Sacramento valley, forming a wide and irregular belt, in which are many rich placers; those in the vicinity of Yreka yielding a large amount of gold. The gold obtained at Port Orford is mingled with a heavy black sand, from which it is separated with considerable difficulty. It is also associated with platinum, iridium, and osmium, which, for the same reason, serve to impair its value.

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CHAPTER VIII.

ECONOMICAL GEOLOGY.

BUILDING MATERIALS IN THE VICINITY OF SAN FRANCISCO.—SAN FRANCISCO SANDSTONE.—GRANITE FROM HONG KONG.—OF TOMALES BAY.—LIMESTONE OF TOMALES BAY.—SANDSTONES OF BENICIA.—SANDSTONE AND TRAP OF VACAVILLE.—WANT OF BUILDING STONE ON THE SACRAMENTO AND FEATHER RIVERS.—TRAP NEAR UPPER END OF THE VALLEY.—FROM FORT READING TO THE COLUMBIA, TRAP EVERYWHERE ON OUR ROUTE.—GOLD.—NO NEW DEPOSITS DISCOVERED.—COUNTRY COVERED BY RECENT VOLCANIC MATTER.—GOLD OF PORT ORFORD.—COAL.—EFFORTS TO FIND TRUE COAL ON THE WESTERN COAST.—COOSE BAY COAL; GEOLOGICAL POSITION; PHYSICAL AND CHEMICAL CHARACTERS; ECONOMICAL VALUE.—COAL OF BELLINGHAM BAY; GEOLOGICAL POSITION; EXTENT AND THICKNESS OF THE BEDS; ASSOCIATED FOSSILS.—MIOCENE FLORA.—LIGNITE BEDS OF THE UPPER MISSOURI.—CHEMICAL AND PHYSICAL CHARACTER OF BELLINGHAM BAY COAL.—ITS ECONOMICAL VALUE.—COAL OF VANCOUVER'S ISLAND; GEOLOGICAL POSITION.—CRETACEOUS ROCKS.—PARALLELISM OF THE CHALK AND TERTIARY OF THE UPPER MISSOURI WITH SIMILAR STRATA ON THE PACIFIC COAST.—PHYSICAL CHARACTER OF THE COAL AND ITS CHEMICAL COMPOSITION.—COAL OF CAPE FLATTERY, PROBABLY THE EQUIVALENT OF THE LIGNITES OF THE COWLITZ AND COOSE BAY.—COAL OF SANTA CLARA, CALIFORNIA.—COAL MARKET OF SAN FRANCISCO.—COAL OF THE LOTA MINE, CHILI.—COAL OF AUSTRALIA.—COAL FROM THE EASTERN STATES.

BUILDING MATERIALS.

VICINITY OF SAN FRANCISCO.

THE only desirable building stone in the vicinity of San Francisco is the sandstone which is fully described in the first chapter of the report, where its fitness for architectural purposes is alluded to. It is very accessible, readily quarried and wrought, and will supply a cheap building material in exhaustless quantities. Some varieties of this stone, especially that quarried on Yerba Buena island, will even answer the demands of ornamental architecture, being to a considerable degree handsome and durable. For more elaborate and expensive structures, however, a more resistant as well as beautiful material will be sought; something which should fill the place of the granites, marbles, and finer freestones used in the eastern cities. Granite is already used to some extent in San Francisco, and it is now, for the most part, imported from Hong Kong, in China. In that part of California which we visited it was observed in but one or two localities. From Tomales bay I obtained specimens of granite which seems well adapted to architectural purposes. It is composed of small crystals of white felspar and quartz, with minute scales of black mica, and forms a very compact and durable as well as handsome stone. There is also, on Tomales bay, a light-colored crystalline limestone, which, when obtained in blocks of sufficient size, will make an excellent building stone. It is quite extensively used for making quicklime. I have also seen specimens of metamorphic limestone, obtained in various parts of the Sierra Nevada, which, for beauty and durability, will almost rival the white marble of Vermont or the Potomac. The sandstones which are quarried in the vicinity of Benicia are similar in character to those of San Francisco, but are softer and less desirable for architectural purposes than some found in the immediate vicinity of the city. From Benicia to Vacaville, the San Francisco sandstone is accessible at many points, and the hills which border the upper end of Suisun bay and Suisun valley on the west are composed of compact trap, which will afford a resistant and durable building material, but one wrought with

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some difficulty. The central portions of the Sacramento valley are entirely destitute of building stone, but the foot hills of the mountains which border it on either side will furnish trap, granite, or sandstone, in abundance, and within a distance which will render them available for all the wants of railroad construction. Near the upper end of the Sacramento valley the hills which border it are composed of trap, much of which would form an excellent building material, and would be everywhere accessible. From this point to the Columbia river, over all parts of our route, trap rock exists in abundance, and varieties would be everywhere attainable which would meet any want of building stone that might arise.

GOLD.

From the fact that other portions of California and Oregon had proved to be so rich in gold, especial interest was excited in our exploration of so much new territory by the anticipation that we might discover other localities in which this precious metal might be obtained. In no part of the region which we traversed, however, after leaving the Sacramento valley, was I able to detect any good evidence of its existence. Nearly all portions of our route are covered by accumulations of recent volcanic matter, by which the underlying rocks are as completely concealed as though the whole country was buried under a heavy bed of snow.

In many localities which we visited there are exposures of metamorphic slates, but they are nowhere talcose in character, nor contain veins of quartz, which would be the repositories of gold. In almost every stream which we crossed an effort was made by "panning" to obtain "the color," but uniformly without success. At the point where we left Pit river the boulders of quartz and other rock found in the bed of the stream led me to suppose that, at some point higher up in its course, the rocks might be found which usually contain it. The metamorphic slates there exposed have a more promising appearance than elsewhere, and in that vicinity I obtained the only traces which I saw of copper. From these circumstances I was led to believe that here, if anywhere on our route, valuable deposits of metal might be discovered. In the Klamath and Des Chutes basins the surface is either occupied with plateaus, or hills of trap, or by stratified tufas, or infusorial marls. The gold of Port Orford has already been alluded to, but I was not able to examine the geology of the vicinity sufficiently to trace it to its source. Gold mining is there carried on empirically, as in most parts of California, and it is worth an effort, on the part of those who may have the opportunity, to determine the law upon which the accumulations of gold in that vicinity depend.

COAL.

The want of this mainspring of modern progress, which has been felt by the inhabitants of California, has been supplied, only imperfectly, from the eastern States, or from other countries; and the price paid for coal transported from great distances has been so high that they have naturally felt a deep interest in the discovery of deposits of it within their own borders. Their efforts, with this end in view, have, however, been attended with but partial success. Beds of lignite have been found in various locations, which have served for a time to excite, and, subsequently, to disappoint the hopes of their discoverers. Although the fact has frequently been announced in the journals, no true coal had been found in California or Oregon at the date of our arrival in San Francisco. About the time of our arrival in San Francisco, however, the carbonaceous deposits on the shores of Coose bay began to attract the attention of

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the public, and it was confidently believed that there had at last been found beds of bituminous coal equal in quality to that imported from the eastern States.

I had an opportunity of examining several cargoes of Coose bay coal at Portland, Oregon, and San Francisco; and from Mr. Northrup, of Portland, Messrs. Flint, Peabody & Co., of San Francisco, and from others, I have received full descriptions of the mines, and much interesting information in reference to the character and extent of the coal deposits. Subsequently, through the kindness of Lieutenant W. P. Trowbridge, U. S. A., I received a map of the bay and of the locality where the mines are situated, and a section across from Point Arago to the bay, including the strata of coal which are worked; also drawings of a large number of the fossils taken from the associated strata, very beautifully executed by Mr. Bridgens, of San Francisco. I was able to bring home a suite of specimens of the coal, of which I have since made chemical analyses. From this material I am able to make the following report:

COOSE BAY COAL.

Geological position.—This coal is interstratified with sandstones and shales, which form a series several hundred feet in thickness, the strata being very much disturbed by intrusion of trap rock, some of them being inclined at an angle of 45°. The beds of coal are found in the upper part of the series, being most fully developed on the shores of the bay, where the strata are much less disturbed than nearer Cape Arago. From the description and section given by Mr. Higgins, I infer that a line of upheaval, with a northwesterly trend, passes between Coose bay and the ocean, giving character to the headland of which Cape Arago is the extremity, and tilting up the stratified rocks on either side. Several of the strata associated with the coal are highly fossiliferous, most of the fossils being marine mollusca. Impressions of plants are also found, but none are represented in the drawings of Mr. Bridgens. Among the fossil shells which he has figured, I recognize *Nautilus*, *Arca*, *Cardium*, *Tellina*, *Nucula*, *Natica*, *Fusus*, *Cerithium*, *&c*, with bones of fishes. It is impossible to be certain with reference to the species of these fossils, but they have all a general resemblance to those obtained from the sandstones and shales of the Columbia, and some of the species are probably the same. Those portions of the series from which the fossils come are evidently tertiary, and there is little doubt that the series, as a whole, is identical with that of the Columbia, which has been pronounced by Mr. Conrad to be Miocene.

The coal occurs in several distinct strata, three of which are represented in Mr. Higgins' section. They are apparently confined to the upper portions of the series which I have mentioned. The most important stratum varies considerably in thickness in different localities, its maximum being about 9 feet. These beds of coal are said to extend over a large area in the vicinity, and have been traced many miles inland.

Physical and chemical character.—The coal is bright, black, and handsome, and when first mined has much the appearance of some of the bituminous coals of the Mississippi valley; most resembling those from the coal fields of Illinois and Iowa. Upon a closer examination, however, it is readily seen to be a tertiary lignite, most of it exhibiting very distinctly the structure of the wood from which it has been formed. I have seen masses of several hundred pounds weight, which were evidently portions of the carbonized trunks of trees of large size. In these, the rings of annual growth, knots, and branches, were almost as plainly perceptible as in recent wood. Like most of the lignites of the west, though firm when first mined, having a conchoidal

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fracture, somewhat resembling Wigan cannel, upon exposure to the air for any length of time it cracks up into a thousand cubical fragments. It burns freely, producing a bright cheerful blaze and considerable heat, but is more flashy, and has far less heating power than the best bituminous coals.

A proximate analysis gives me for its composition the following formulæ:

Fixed carbon	46.54
Volatile matter	50.27
Ashes	3.19

Coke, 49.73, dark, friable, and of but little value. The amount of gas is large, but of low illuminating power. This coal apparently contains very little bi. sulph., iron, or other injurious impurities, and is extensively used in San Francisco, and was selling, at the time of our visit, at $22 per ton, in small quantities, but could be bought, by the cargo, at $16 to $18 per ton.

COAL OF BELLINGHAM BAY, W. T.

Geological position.—This coal is found interstratified with sandstones and shales on the shores of Bellingham bay. Lieut. W. P. Trowbridge, U. S. A., while superintending the construction of light-houses on that part of the coast, made a careful measurement of the strata of the section in which the beds of coal are exposed, of which the results have been published in the geological report of Mr. W. P. Blake, contained in vol. V, U. S. P. R. R. Reports.

The section exposed, when measured by Lieut. Trowbridge, consisted of about 2,000 feet of shales, sandstones, and coal, of which the coal presented the enormous aggregate of 110 feet. It is possible, however, that the series is, in part, composed of repetitions of the same members, as the strata are inclined at a high angle, and are much convoluted and disturbed in all that region.

Many of the shales are fossiliferous, and vegetable impressions are particularly abundant. These consist, for the most part, of the impressions of dicotyledonous leaves, and are similar in general character; and some of them specifically identical with those collected on Frazer's river by the United States Exploring Expedition, under Capt. Charles Wilkes. Among them are species of *Platanus*, *Acer*, *Alnus*, *&c.*, as yet undescribed. There is also a *Taxus*, or *Taxodium*, and a *Juniperus*. It is probable that all the dicotyledonous species there represented are extinct. The *coniferae* may not be so. A sufficient number of well marked specimens has, however, not yet been collected to determine this question.

The flora of the coal deposits of Bellingham bay is remarkably like that of the lignite beds of the upper Missouri, the genera being nearly all represented on the Missouri, and some of the species are identical.

The lignite beds of the Missouri are undoubtedly Miocene, and it is very difficult to distinguish some of the species found in them from those of the Miocenes of Austria and of the Island of Mull.

The strata exposed on Bellingham bay, both in their lithological character and their fossils, are closely related to the sandstones and shales of the Columbia and Coose bay, and are, probably, portions of the great San Francisco group, which forms the most striking feature of the geology of the coast mountains.

The mines at Bellingham bay were among the first opened on the western coast, and have already furnished a large quantity of coal for the San Francisco market.

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Physical and chemical characters.—While having much the appearance and character of that from Coose bay, this coal is harder and better, and more resembles the carboniferous coals of the Mississippi valley. Several analyses give me for its composition—

Fixed carbon	47.63
Bitumen	50.22
Ashes	2.15

Its economical value and adaptation to the different purposes for which coal is used are very similar to those of the Coose bay coal, but commands a somewhat higher price in market. When I was in San Francisco, coal from Bellingham bay was selling for $22 per ton.

VANCOUVER'S ISLAND COAL.

Geological position.—Very little has heretofore been known of the geology of Vancouver's island except that extensive deposits of coal existed there. The island is inhabited by Indians of a peculiarly warlike character who have always been hostile to the whites, and have rendered it dangerous to attempt to explore its geology.

It is also said to be, for the most part, covered with a dense forest and tangled thickets of vine-maple, which present almost insurmountable obstacles to any one who should attempt to penetrate the interior. At Nanimo, however, a small English colony has been established, and the deposits of coal which are found there have been, to some extent, worked for the San Francisco market, and to supply the English steamers which sometimes touch there.

I have been able to obtain but little information in reference to the geological associations of the coal of Vancouver's island; the only persons who have visited the island, to my knowledge, having examined only that portion immediately adjacent to the coal mines of Nanimo. They have also contented themselves with a hasty inspection of the mines, and with collecting the fossils, which seemed to be abundant, without taking much note of the relative positions of the strata which contain them. I have received from them, however, a full suite of specimens of the coal, and a series of fossils of great beauty and of special geological interest.

The fossils consist, for the most part, of marine shells, of which the most conspicuous are *Ammonites*, *Baculites*, &c., of large size, and evidently derived from cretaceous rocks. These fossils occur in calcareous concretions and so much resemble, in their mode of fossilization, those brought from the upper Missouri by Mr. Meek and Dr. Hayden, that they would be supposed to have come from the same locality. Of the species obtained from Vancouver's island many are new, but some are identical with those from the upper Missouri and fully establish the parallelism of the cretaceous strata which occur on different sides of the Rocky mountains. The discovery of cretaceous fossils, as far west as the Island of Vancouver, seemed to me a fact of peculiar geological interest; not only as extending over an area far greater than has been suspected the cretaceous rocks of the upper Missouri, but as furnishing a basis upon which we shall probably find the Miocene tertiaries to rest, as on the eastern slope of the Rocky mountains. It is not uninteresting to note, also, that the Miocene strata of the upper Missouri are peculiarly characterized by beds of lignite, which have attracted the attention of every traveller who has passed up or down that river; and that, on descending the Columbia, below the region covered with recent volcanic material, we find a series of Miocene deposits, which are also associated with great accumulations of carbonaceous matter.

It is true that much of the lignite of the Pacific coast is more compact, approaches nearer to

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true coal, and furnishes a better fuel than that of the upper Missouri, but this is doubtless, in a great degree, due to the metamorphic action of erupted rocks which, as we have seen, have in so many places disturbed the tertiary strata. The close affinity, and probable synchronism, of the lignites of the upper Missouri and those of the Pacific coast is proved from the flora of these deposits, and has already been referred to. Until further information shall be obtained in reference to the relationship existing between the cretaceous rocks of Vancouver's island and the coal found there, the age of that coal can only be conjectured. The character of this coal, its resemblance to that of Bellingham bay, and the proximity of the two localities, give us reason to suspect that they belong to the same age and are equivalents of each other.

And it is at least presumable that the strata which enclose the coal overlie the cretaceous rocks occupying the same relative positions as the chalk and lignite beds of the Missouri.

In a preceding chapter of this report I had occasion to notice the existence of cretaceous rocks near the upper end of the Sacramento valley, and, in the same connexion, referred to exposures of carboniferous limestone in localities not far distant. When the connexion shall be traced between these deposits, and the relations which they hold to the widely spread tertiary strata of the Pacific coast ascertained, it seems not improbable that, having there at different points all the principal elements which compose the geological structure of the eastern slope of the Rocky mountains, we shall be able to combine them in such a way as to establish a much more complete parallelism between the eastern and western sides of the continent than has been hitherto suspected. Among the fossils brought from Vancouver's island there is a large number, including many species, which are apparently not cretaceous, and which are very unlike any of the many tertiary fossils which have been collected at various points on the western coast. They are contained in a soft, greenish sandstone, and have been regarded by Mr. Meek, to whom they have been submitted, as probably indicative of strata of Jurassic age. The genera represented are, perhaps, not peculiar to that period, and the species are, without exception, new; but he regards them as presenting forms which are rather Oolitic or Jurassic, than cretaceous or tertiary. If the strata from which they are derived should be found to occupy a lower position than those yielding the cretaceous fossils, we should, perhaps, have then a representative of the Jurassic strata which underlie the chalk on the Atlantic coast, and probably throughout a large area in the interior of the continent.

PHYSICAL AND CHEMICAL CHARACTERS.

The coal from the Island of Vancouver resembles in many respects, as has been stated, that from Bellingham bay, and is more compact and crystalline than any of the tertiary lignites I have seen. It is as hard and handsome as many of the coals derived from the basins of the Mississippi valley, and, like many of the coals of the carboniferous period, exhibites scales of carbonate of lime in its joints. Its chemical composition, however, shows that, although a very well finished article, it is comparatively of recent date.

It is composed of—

Fixed carbon	51.81
Volatile matter	44.30
Ashes	3.89
Total	100.00

I saw several cargoes of this coal in San Francisco, where it has been used for several years.

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It is regarded as very similar in its character to that of Bellingham bay, and commands about the same price.

COAL FROM CAPE FLATTERY.

This coal I have marked as coming from Cape Flattery, that being the nearest point to the locality from which it is derived, whose position is generally known. It is, in fact, obtained some 25 miles lower down on the coast. I owe to the kindness of Lieut. Trowbridge, U. S. A., the specimens which I have of this coal, and also whatever information I possess in reference to its geological position. It occurs associated with similar shales and sandstones to those which enclose the coal of Bellingham bay, and is doubtless of the same age. From what I have been able to learn of the geology of this part of the coast, it seems probable that the tertiary strata of Bellingham bay extend continuously, or with but local interruptions, to the Columbia.

The character of the Cape Flattery coal is similar in all respects to that of Coose bay, and hand specimens from the two localities are undistinguishable. Its chemical composition is also nearly identical, and whatever has been said of the character or value of the former is equally applicable to the latter. Its chemical composition is as follows:

Fixed carbon	46.40
Volatile matter	50.97
Ashes	2.63
	100.00

COAL FROM SANTA CLARA, CALIFORNIA.

This coal, or lignite, occurs 12 miles back from Santa Clara, and is said to form a stratum 3 feet in thickness, and is overlaid by a sandstone containing marine shells. In the small specimens of this rock which were given me by Lieut. Trowbridge, but a single species of fossil shell is distinguishable, though this is represented by considerable numbers. This shell is that of a gasteropodous mollusc, and a type of a new genus, described by Mr. Conrad under the name of *Schizopyga*, and figured in this report, plate 1, fig. 1. The coal, or rather lignite, from this locality exhibits some variety in appearance and purity; some of it showing very plainly the structure of the wood from which it has been formed, while other portions resemble a consolidated carbonaceous mud, and contain a large proportion of earthy matter. No analysis has been made of it; but while the better portions closely resemble the coal of Coose bay, it is evident that, as a whole, it is decidedly inferior as a fuel to the coal from that locality.

Aside from the coals I have mentioned, there are annually sold in the San Francisco market many cargoes from Chile, Australia, and the eastern United States. Of these, the anthracite and semi-bituminous coals from the eastern States are much preferred, and always command a higher price. The price of anthracite coal during my stay in the city varied from $37 to $40 per ton, while that from Chile and Australia ranged from $25 to $27.

The Chilean coal, of which I saw large quantities, was all derived from the Lota mine; of which the coal has been carefully examined, and an analysis published (in the report of the Naval Astronomical Expedition, vol. II, page 105,) by Professor J. L. Smith. I was much interested in noting the very evident similarity which exists between the Chilean coal and that of the northwestern coast. It apparently belongs to the same geological epoch, and indicates the

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extent of the area over which the tertiary deposits are spread along the North and South American Pacific coasts.

The coal of Australia has been fully described by Professor Dana in the geology of the exploring expedition, and is only interesting in this connexion on account of the amount annually sold in the San Francisco market, and for comparison with those which have been already described. This coal has more of the laminated structure, the rhombohedral fracture and general appearance of the older coals, but, from its softness and the evidently large quantity of sulphuret of iron which it contains, it cannot claim the first rank as a fossil fuel.

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No. 2.

DESCRIPTION OF THE TERTIARY FOSSILS COLLECTED ON THE SURVEY.

BY T. A. CONRAD.

The California fossils, described from the collection of Dr. Newberry, consist of shells, which appear to me to represent the Miocene period, or to have existed contemporaneously with the fossil fauna of Virginia referred to that epoch. The few shells from Gatun, Isthmus of Darien, are not sufficient to indicate precisely the geological age of that vicinity. The well known univalve, *Malea ringens*, is one of the number, a shell which now exists only in the Pacific, and I believe the genus is unknown in the Atlantic. The probability is, therefore, that posterior to the Eocene period the Pacific was separated from the Caribbean sea by a narrower strip of land than at present, and that while the land was rising towards the Pacific it was probably sinking on the eastern coast.

CALIFORNIA FOSSILS.

UNIVALVE.

SCHIZOPYGA, *Conrad.*

Bucciniform ; columella concave, plicate ; lower part of body volution deeply channelled, the channel emarginating the columella.

Schizopyga Californiana, Plate II, fig. 1. Volutions rounded, having revolving ribs and longitudinal furrows, giving the ribs a nodulous character ; basal excavation profound.—Proceedings of Acad. Nat. Sc., Dec., 1856, p. 315.

Locality.—Santa Clara, Cal.—Dr. Newberry.

The above genus is probably related to Cancellaria.

BIVALVES.

CRYPTOMYA, *Conrad.*

Cryptomya ovalis, Pl. II, fig. 2. Oval, compressed, posterior end truncated ; umbonal slope angulated on the umbo ; beaks medial ; basal margin medially truncated ; disk medially flattened.—Proceedings Acad. Nat. Sc. for Dec., 1856, p. 314.

Locality.—Monterey county, Cal.—Dr. Newberry.

Rather smaller than the recent *C. californica*, less regularly oval, inequilateral, &c.

THRACIA, *Leach.*

Thracia mactropsis, Pl. II, fig. 3. Subtriangular, subequilateral, ventricose ; anterior side cuneiform or subrostrated, posterior end regularly rounded ; ligament margin very oblique ; base

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regularly and profoundly rounded; umbonal slope abruptly rounded; summit prominent, posterior to the middle of the valve; anterior extremity angular. Length 1 inch.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 313.

Locality.—Monterey county, California.—Dr. Newberry.

MYA, *Lin.*

Mya Montereyana, Pl. II, fig. 4. Suboval, slightly ventricose, thin, inequilateral; summit hardly prominent; anterior end subtruncated? posterior end acutely rounded, the extremity situated more nearly on a line with the beak than the base; disk concentrically rugoso-striate. Length $1\frac{1}{4}$ inches.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 313.

Locality.—Monterey, Cal.—Dr. Newberry.

This and the preceding fossil belong to the same rock in which the Schizopyga occurs, the group having no resemblance to that of Estrella, or other localities referred to in this paper.

Mya ? subsinuata, Pl. II, fig. 5. Somewhat sinuous, ovate, slightly reflected at both ends; contracted medially or from beak to base.

Locality.—Monterey county.

ARCOPAGIA, *Leach.*

Arcopagia medialis, Pl. II, fig. 6. Oval, both valves slightly ventricose anteriorly; upper valve much contracted or concave towards the umbonal slope, which is angulated; post umbonal slope slightly contracted in the middle, emarginate at base; the corresponding slope of the lower valve deeply folded, reflected towards the extremity; disks rugoso-striate concentrically.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 314.

Locality.—Monterey county, Cal.—A. S. Taylor.

This shell is proportionally longer than *A. biplicata*, Conrad, of the Maryland Miocene, but the general resemblance is noticeable and adds to the probability that the very remote strata in which they occur are parallel.

TAPES, *Sowerby.*

Tapes linteatum, Pl. II, fig. 7. Oblong-oval, ventricose; buccal side short, extremity obtusely rounded; anal side elongated, end regularly rounded; ligament margin long, oblique, straight; disks radiated with fine, unequal lines, except on the post-umbonal slope, which is entire.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 314.

Locality.—California.—Dr. Newberry.

ARCA, *Lin.*

1. *Arca canalis*, Pl. II, fig. 8. Subtrapezoidal, ventricose; ribs 24 to 26, flattened, scarcely prominent, divided by a longitudinal furrow; disk concentrically wrinkled; umbo ventricose; summits prominent, remote from the centre.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 314.

Locality.—Santa Barbara, Cal.—Dr. Newberry.

2. *Arca trilineata*, Pl. II, fig. 9. Trapezoidal, somewhat produced, inequilateral, ventricose; ribs 22–24, scarcely prominent, square, wider than the intervening spaces, ornamented with three impressed or four raised lines; disks concentrically wrinkled; summits prominent; beaks approximate. Length 3 inches.—Proceedings Acad. Nat. Sciences, Dec. 1856, p. 314.

Locality.—Occurs with the preceding.

3. *Arca congesta*, Pl. II, fig. 10. Rhomboidal, ventricose, inequilateral; ribs about 27, con-

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vex on the back, wider than the intervals, which are transversely striate; anterior ribs crenate; ligament margin elevated; posterior end obtusely rounded; summits prominent. Length, $\frac{5}{8}$ inch.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 314.

Locality.—California.—Dr. Newberry.

AXINÆA, *Poli.* PECTUNCULUS, *Lam.*

Axinœa barbarensis, Pl. III, fig. 11. Lentiform, subequilateral, concentrically wrinkled; ribs about 37, scarcely prominent, flat, defined by an impressed line, wanting on the submargins and obsolete towards the base; summits slightly prominent.

MULINIA, *Gray.*

M. densata, Pl. III, fig. 12. Subovate, ventricose, thick, very inequilateral; posterior side very short comparatively, contracted; extremity subtruncated, much above the line of the base; posterior basal margin very oblique and contracted; anterior end obliquely truncated; anterior basal margin rounded; summits prominent, distant; lateral teeth very robust and prominent; inner margin entire.—Proceedings Acad.Nat. Sciences, Dec., 1856, p. 313.

Locality.—Santa Barbara and shores of San Pablo bay? California.—Dr. Newberry.

DOSINIA, *Scopoli.*

1. *Dosinia longula.* Regularly ventricose, inequilateral, longitudinally oval; margins and base regularly rounded; summit prominent; buccal margin more obtusely rounded than the anal.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 315.

Locality.—Monterey, Cal.—Dr. Newberry.

2. *Dosinia alta*, Pl. III, figs. 13*a* and 13*b*. Obtusely subovate or suboval from beak to base; posterior margin curved, profoundly oblique; base regularly and rather acutely rounded; summits prominent, oblique; surface marked with numerous fine, concentric, impressed lines; beaks medial. Height, 4 inches.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 315.

Locality.—Monterey, Cal.—Dr. Newberry.

PECTEN, *Lin.*

Pecten Pabloensis, Pl. III, fig. 14. Orbicular, compressed, thin, concentrically wrinkled; ribs 18–20, slender; little prominent, with an intermediate radiating line.

Locality.—San Pablo bay, Cal.—Dr. Newberry.

PALLIUM, *Klein.*

P. estrellanum, Pl. III, fig. 15. Suborbicular; lower valve ventricose, slightly undulated; ribs 17, broad, little prominent, convex, with an intermediate linear rib, from which the larger ribs are separated by an impressed line; upper valve convex, somewhat undulated, ribs flattened, and the intermediate small ribs with a longitudinal impressed line on the lower part of the valve.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 313.

Locality.—Estrella valley, Cal.—Dr. Newberry.

JANIRA, *Shum.*

Janira bella, Pl. III, fig. 16. Subtriangular; inferior valve convex, ribs 14 or 15, square, about as wide as the intervening spaces, very prominent, some of them with one or two longitudinal obsolete lines; disk finely wrinkled concentrically; upper valve flattened, deeply

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depressed towards the apex; ribs rather narrower than those of the opposite valve, obscurely bicarinated above, disk ornamented with close, fine, squamose, concentric wrinkles. Length, 4 inches; height, 3¾ inches.—Proceedings Acad. Nat. Sciences, Dec., 1856, p. 312.

Locality.—Santa Barbara, Cal.—Dr. Newberry.

OSTREA, *Linn.*

Ostrea Titan, Pl. IV, fig. 17, Pl. V, fig. 17*a*, profile. Produced from beak to base, straight or slightly curved, substance very thick, coarsely laminated; upper valve flat, very thick, somewhat gibbous; lower valve profoundly ventricose, umbonated, the summit rising above the beak of the opposite valve. Length, .—Proceedings Acad. Nat. Sciences, 1855.

Locality.—San Luis Obispo, California.

FOSSILS OF GATUN, ISTHMUS OF DARIEN.

MALEA, *Valenc.*

Malea ringens, Pl. V, fig. 22.

Dolium ringens, (Cassis,) Swainson.

Locality.—Gatun. This shell inhabits the Pacific coast of South America, and the genus is unknown in the Atlantic.

TURRITELLA, *Lam.*

1. *Turritella altilira*, Pl. V, fig. 19. Subulate, carinated; volutions with 2 distant, elevated, revolving, crenulated ribs, interstices with revolving lines; body volution bicarinated at the angle.

Locality.—Gatun.—Dr. Newberry.

2. *Turritella Gatunensis*, Pl. V, fig. 20. Subulate; volutions each with 2 slightly concave spaces; body volution ventricose, much larger than the penultimate, having about 20 revolving lines, 7 or 8 of which are on the base, which is flattened; 3 lines on the body volution larger than the others, the 2 lower ones remote.

Locality.—Occurs with the preceding.

TRITON, *Lam.*

An imperfect cast of an unknown species occurs with the preceding.

I have compared the above three univalves with what recent species and figures I have access to, and cannot identify them; but if they should be representatives of existing shells, they will doubtless prove to be inhabitants of the Pacific coast, of the Isthmus, or of South America.

CYTHEREA? *Lam.*

Cytherea? (Meretrix) Dariena? Pl. V, fig. 21. Meretrix Dariena, *Con.* Desc. of Foss. and Shells collected in Cal., by Wm. P. Blake, p. 18. I have referred this shell to Cytherea, as it is probable that Venus meretrix may prove the type of a genus distinct from Cytherea.

TAMIOSOMA, *Conrad.*

An elongated tube, apparently entire, porous and cellular throughout its substance; interior filled with numerous irregularly-disposed vaulted cells connected by longitudinal slender tubes, funnel-shaped beneath; aperture resembling that of Balanus.

Tamiosoma gregaria, Pl. IV, fig. 18. Subquadrangular, elongated, longitudinally furrowed

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and striate, and having fine, undulated, transverse lines; mouth small, oblique; upper part of the tube oblique, deeply indented or Balaniform, and coarsely striated longitudinally. Length 8 inches,

Locality.—Monterey county, California.—A. S. Taylor. Growing in clusters like Balani. No sutures, indicating separate valves; cells very thin plates, convex surface downwards.

PANDORA, *Lam.*

Pandora bilirata, Pl. V., fig. 25, Conrad.—Proceed. Acad. Nat. Sciences for 1855, vol. vii, p. 267.

Locality.—Santa Barbara, Cal.

CARDITA, *Brug.*

Cardita occidentalis, Pl. V., fig. 24, Ib.

Locality.—Santa Barbara.

DIADORA, *Gray.*

Diadora crucibuliformis, Pl. V., fig. 23, Ib.

Locality.—Santa Barbara, Cal.

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No. 3.

REPORT UPON AN ANALYTICAL EXAMINATION OF WATER AND MINERALS FROM THE HOT SPRINGS IN DES CHUTES VALLEY.

CONDUCTED UNDER THE DIRECTION OF PROF. E. N. HORSFORD.*

LETTER FROM PROF. E. N. HORSFORD.

HARVARD UNIVERSITY, CAMBRIDGE, *May* 25, 1857.

SIR: I enclose to you the report of my assistant, Mr. L. M. Dornbach, upon the minerals and water of the hot siliceous springs of the Des Chutes valley, Oregon, which you placed in my hands.

I am, very respectfully, yours,

E. N. HORSFORD.

Lieut. H. L. ABBOT, *U. S. Top. Engs.*

REPORT BY MR. L. M. DORNBACH.

The notes accompanying the specimens are as follows:

"The sample of water is taken from one of a number of thermal springs which give a peculiar character to a region some miles in extent. The temperature of the water is about 145° Fahr., and the basins into which it flows are filled with floating jelly-like masses of silica. A white incrustation is formed upon all objects lying in the water. The volcanic tufas in the vicinity of the springs are accurately stratified, horizontal, and nowhere disturbed. The stream and hot water from the springs have penetrated the strata in all directions, producing complete metamorphosis of the different materials of which they are composed, converting the porous pulverulent tufas, by a succession of changes, into a kind of jasper."

The method adopted in the qualitative analysis for the detection of the alkalies was to fuse one part of the finely pulverized mineral with four parts of a mixture of three parts of carbonate of baryta and one part chloride of barium. The fused mass was next digested with hydrochloric acid to decompose the silicate of baryta; then evaporated to dryness to expel most of the free acid, treated with water and the silica filtered off. The baryta, with the iron, lime and alumina was precipitated by adding carbonate of ammonia, the filtrate was then evaporated to dryness, the ammoniacal salts expelled, and the chloride of magnesium converted into insoluble mag-

* *Note by Lieut. Abbot.*—It is proper to state that Prof. Horsford conducted these analyses in his laboratory, without expense to the government. The specimens were collected at the most interesting locality upon our route, in a geological point of view, and the results of the analysis are of great value in illustrating the action of thermal springs.

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nesia by ignition. The residue, if any, was treated with hot water, which dissolved the alkaline chlorides; these were then tested for by the usual methods. Magnesia being absent when alkalies were found, their quantitative estimation was conducted in the same manner, with the exception that the baryta was precipitated by adding sulphuric acid in slight excess. From the filtrate the iron and alumina were precipitated by ammonia and separated, after igniting, weighing, and redissolving in hydrochloric acid, by caustic potassa. The lime by oxalate of ammonia, the filtrate evaporated and ignited left the alkalies in the state of sulphates. If the alkalies were absent the mineral was easily decomposed by digesting for several hours with concentrated hydrochloric acid, and the different substances separated by the method stated. The water was estimated by igniting the substance after drying, at 212° Fahr., for forty-eight hours. In determining the specific gravity, coarse fragments of the specimens were put in a specific gravity flask, partially filled with water, and placed under an exhausted receiver, thus expelling the air from the porous mass. The temperature at which this determination was made was 15° C, or 59° Fahr.

In the following arrangement of the results of analysis, all from A to G are friable tufas, unchanged by action of water; H is a specimen of incrustation, while all the remainder have been changed more or less by the action of the thermal springs; and, in consequence, have acquired greater hardness. Both the changed and unchanged have no cleavage, but break into irregular fragments, having an uneven and hackly fracture.

A has a specific gravity of 2.2505; of fine granular structure; color, yellowish, ochreous, from sesquioxide of iron; with numerous irregular nodules of clear quartz crystals, and quartz colored by iron and manganese interspersed through the entire mass. No cleavage, breaks into irregular fragments; fracture uneven, opaque, very soft and friable.

COMPOSITION.

$\dddot{S}i.$ 54.386, $\dddot{A}l.$ 20.665, $\dddot{F}e.$ 9.945.
$\dot{C}a.$ 1.894, $\dot{H}.$ 12.919 = 99.507.

B. Specific gravity, 2.1947; coarsely granular; fracture uneven; color, whitish gray, resembling gray sandstone in appearance very much; easily crushed.

COMPOSITION.

$\dddot{S}i.$ 80.837, $\dddot{A}l.$ 6.401, $\dddot{F}e.$ 4.680.
$\dot{C}a.$ .384, $\dot{H}.$ 6.932 = 99.234.

C. Specific gravity, 1.950; finely granular; color, white; resembles chalk not only in color, but in fracture and softness.

COMPOSITION.

$\dddot{S}i.$ 84.721, $\dddot{A}l.$ 1.704, $\dddot{F}e.$ 4.589.
$\dot{C}a.$ 1.009, $\dot{H}.$ 7.977 = 100.

D. Specific gravity, 2.2466; coarsely granular; irregular fracture; color, reddish; resembling specimen B very much in texture and friability, but owing to a larger per cent. of sesquioxide of iron, it is more nearly a red sandstone.

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COMPOSITION.

$\dddot{S}i.$ 74.758, $\ddot{A}l.$ 4.517, $\ddot{F}e.$ 9.152.
$\dot{C}a.$ 1.469, $\dot{H}.$ 10.146 = 100.042.

E. Specific gravity, 2.2431; structure, granular; color, gray; differs from B only in possessing a somewhat finer granular structure, and is slightly tinged red by a larger quantity of sesquioxide of iron.

COMPOSITION.

$\dddot{S}i.$ 81.554, $\ddot{A}l.$ 3.331, $\ddot{F}e.$ 8.076.
$\dot{C}a.$ 1.443, $\dot{H}.$ 6.137 = 100.541.

F. Specific gravity, 1.970; structure, finely granular; very soft and friable; full of irregular seams or cracks, along which it breaks readily; color, grayish, with yellowish streaks.

COMPOSITION.

$\dddot{S}i.$ 61.020, $\ddot{A}l.$ 13.017, $\ddot{F}e.$ 8.639.
$\dot{C}a.$ 1.257, $\dot{H}.$ 15.292 = 99.215.

G. Specific gravity, 2.000; resembles F in many particulars, and differs from it only in having some small elliptical or spherical portions of half an inch in diameter, perfectly white, while layers surrounding these have a darker shade of gray, thus presenting a motley appearance; and in containing no yellowish streaks, which exist in F, in consequence of containing a larger proportion of sesquioxide of iron.

COMPOSITION.

$\dddot{S}i.$ 75.746, $\ddot{A}l.$ 10.326, $\ddot{F}e.$ 6.016.
$\dot{C}a.$ 1.773, $\dot{H}.$ 7.339 = 101.2.

H. Specific gravity, 2.2705; granular structure; color, grayish; soft and friable; is a deposit from the hot springs, which forms incrustations upon objects in the water.

COMPOSITION.

$\dddot{S}i.$ 1.615, $\dot{C}a,\ddot{C}.$ 40.623, $\dot{N}a,\ddot{C}.$ 45.567.
$\dot{H}.$ and organic matter, 10.623 = 98.398.

The next four, marked *b*, *c*, *d*, and *e*, have been changed by agency of water; differ from the unchanged in possessing superior hardness and specific gravity without differing very much in chemical composition.

b. Specific gravity, 2.2774; coarsely granular structure; compact; color, gray, with a reddish tint; a complete sandstone.

COMPOSITION.

$\dddot{S}i.$ 81.592, $\ddot{A}l.$ 4.144, $\ddot{F}e.$ 5.096.
$\dot{C}a.$ 1.627, $\dot{H}.$ 6.578 = 99.037.

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c. Special gravity, 2.3242; finely granular; hard; is composed of alternate layers, one of gray color, the other of pinkish hue; does not cleave along the apparent strata, but has an irregular fracture.

COMPOSITION.

$\dddot{S}i.$ 80.401, $\ddot{A}l.$ 3.145, $\dddot{F}e.$ 4.061.
$\dot{C}a.$ 1.365, $\dot{H}.$ 10.750 = 99.722.

d. Specific gravity, 2.490; extreme change of form; structure compact, even; fracture conchoidal, smooth; color, reddish purple; resembles jasper.

COMPOSITION.

$\dddot{S}i.$ 96.507, $\ddot{A}l.$ and $\dddot{F}e.$ 1.181, $\dot{C}a.$ .987.
$\dot{N}a$, trace, $\dot{H}.$ .546 = 99.507.

e. Specific gravity, 2.2542. Granular, compact; can be broken with the nail. Color, grayish white.

COMPOSITION.

$\dddot{S}i.$ 80.891, $\ddot{A}l.$ 12.211, $\dddot{F}e.$ 1.771.
$\dot{C}a.$ 1.181, $\dot{H}.$ 3.211 = 99.265.

The next two, M and N, contain silicate of soda, and some iron as protoxide, as is shown by digesting the mineral in fine powder with some hydrochloric acid, and testing with permanganate of potassa.

M. Specific gravity, 2.371. Fracture hackly, coarse. Full of small cavities of a light yellow color. Color of the mass, greenish gray.

COMPOSITION.

$\dddot{S}i.$ 69.697, $\ddot{A}l.$ 15.685, $\dddot{F}e.$ 2.200.
$\dot{C}a.$ .332, $\dot{N}a.$ 10.00, $\dot{H}.$ 1.186 = 99.100.

N. Specific gravity, 2.346. In appearance differs from the last only in having the cavities in the mass larger and colored darker yellow or red by the sesquioxide of iron.

COMPOSITION.

$\dddot{S}i.$ 81.540, $\ddot{A}l.$ 8.454, $\dddot{F}e.$ 4.227.
$\dot{C}a.$ .684, $\dot{N}a.$ 4.650, $\dot{H}.$ 1.184 = 100.739.

The last specimen had a variable composition and appearance. Vitreous opal of a specific gravity 2.105, slightly streaked yellow, by iron constituting central and principal portions of the mass. Surrounding the opal was a brownish substance, P, and outside this a greenish mineral, O.

O. Specific gravity, 2.392. Coarse, brittle structure; hard. Fracture irregular. Color greenish. Resembles M in all its properties, physical as well as chemical.

COMPOSITION.

$\dddot{S}i.$ 69.455, $\ddot{A}l.$ 12.313, $\dddot{F}e.$ 2.205.
$\dot{C}a.$ 1.908, $\dot{N}a.$ 4.667, $\dot{H}.$ 9.416 = 99.959.

P. Specific gravity, 2.4819. Hard and brittle. Color brownish.

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COMPOSITION.

$\dddot{S}i.$ 70.430, $\ddot{A}l.$ 14.680, $\dddot{F}e.$ 3.047.
$\dot{C}a.$ .322, $\dot{N}a.$ 9.623, $\dot{H}.$ 1.255 = 99.357.

The silica found in the water exists in combination with an alkaline base; since upon evaporation the whole of the residuum is again redissolved in water. But if treated with some strong acid previous to evaporation, one part of silica is obtained in 11,976 parts of water. From the quantity of alkali found, the silica, which separated very soon upon exposure to the air, and which floats in the basins, must, at least in part, be in combination with an alkali, as an alkaline silicate, which the carbonic acid of the atmosphere decomposes, forming an alkaline carbonate. The result of analysis is as follows:

Specific gravity of water, 1.00085. In 10,000 parts there are 13.82 parts of solid matter, not considering the excess of carbonic acid which is expelled during evaporation.

COMPOSITION OF SOLID MATTER.

$\dot{K}.$ .218, $\dot{N}a.$ 6.574, $\dot{C}a.$ .129, Mg. .088.
$\dddot{S}i.$ .835, Fe. trace, Cl. 2.442, $\ddot{C}.$ 4.266.
$\ddot{S}.$ 1.099 = 15.651.

The following arrangement may represent the presumed combinations as they exist in solution:

Water	9984.856
Chloride of potassium	.343
Chloride of sodium	3.501
Chloride of magnesium	.209
Sulphate of lime	.313
Sulphate of soda	1.624
Silicate of soda	1.407
Carbonate of soda	5.916
Free carbonic acid	1.831
	10000.000

The carbonic acid which I have represented as free evidently exists in combination with bases forming bicarbonates.

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No. 4.

CATALOGUE OF THE MINERALS AND FOSSILS COLLECTED ON THE SURVEY.

No	Name.	Locality.
1	Red jasper	Benicia, California
2	Sandstone	----do----do
3	----do	San Francisco, California
4	----do	Santa Barbara, California
5	----do	San Pablo bay, California
6	Volcanic tufa	----do----do
7	Volcanic conglomerate	----do----do
8	----do----do	----do----do
9	----do----do	----do----do
10	Scoria in conglomerate	----do----do
11	Blue limestone	----do----do
12	Calcareous tufa	Near Benicia
13	Tufaceous trap	Hills west of Suisun bay
14	----do	----do----do
15	Granite	Near Sonoma, California
16	Cellular trap	Near Fort Reading
17	----do	Pit river, lower cañon
18	----do	Pit river, upper cañon
19	Alumina—silicious marl, pure white	Pit river, lower cañon
20	----do----do----brown	----do----do
21	----do----do----pure white	Pit river, above upper cañon
22	Green sandstone	20 miles above upper cañon, Pit river.
23	Trachyte, containing crystals of hornblende and glassy felspar	Lassen's butte, California
24	----do----decomposing into felspathic sand, reflecting the sun like snow	
25	Sandstone, cream colored and friable, forming bluffs capped with trap	Shores of Rhett lake
26	Alumina—silicious marl, pure white	Plain about Lower Klamath lake
27	Scoria in sandstone (25)	Natural Bridge, Lost river, O. T.
28	Pumice, coarse	Lassen's butte, California
29	Epidote, with crystals of hornblende	Upper Pit river, California
30	Gray syenite	Upper Pit river
31	Gray porphyry	... do
32	Greenstone	----do
33	Massive quartz, with epidote	----do
34	Black obsidian, in balls	----do
35	Pumice, from Pumice plain	North of Upper Klamath lake

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CATALOGUE—Continued.

No.	Name.	Locality.
36	Obsidian and pumice, in same mass	Crater pass, Cascade mountains, O. T.
37	----do--------do----------	----do--------do--------do--------
38	Obsidian, columnar	----do--------do--------do--------
39	Black basalt, with zeolites	----do--------do--------do--------
40	Amygdaloid, with zeolites	Upper Pit river
41	----do---- -do----------	Crater pass
42	Black basalt, with olivine and mesotype	----do----------
43	Scoria, blood-red	----do----------
44	----do----------	Hill in Des Chutes basin
45	Metamorphic slate	Cascade mountains, latitude 44°
46	Scoria, from melting of last	----do--------do--------do--------
47	Dark green basalt	Crater pass, O. T
48	Pitch stone	Upper Pit river
49	Scoria, red	Mount Hood, O. T
50	Scoria, black	----do----------
51	Vesicular trap	----do----------
52	----do----------	Upper Pit river
53	Quartz	Mount Hood, O. T
54	Pitch stone	Upper Des Chutes river, O. T
55	Infusorial deposit	Pit river, above upper cañon
56	----do----------	Monterey, California
57	----do----------	----do--------do----------
58	----do----------	San Francisco, California
59	----do----------	Sonoma
60	----do----------	Monterey
61	----do----------	Pit river, lower cañon
62	----do----------	----do--------do----------
63	----do----------	Pit river, above lower cañon
64	----do----------	20 miles above upper cañon
65	Alkaline efflorescence	Shores of Rhett lake
66	Red earth	Nee-nee Springs, Des Chutes basin.
67	Infusorial earth	Lost river, O. T
68	----do----------	Lower Klamath lake
69	Deposit from waters of Klamath lake	----------
70	Infusorial deposit	Mpto-ly-as river, O. T
71	----do----------	----do--------do----------
72	----do----------	----do--------do----------
73	----do----------	Banks of Psuc-see-que creek, O. T
74	----do----------	----do--------do--------do--------
75	----do----------	----do--------do--------do--------
76	----do----------	----do--------do--------do--------
77	----do----------	----do--------do--------do--------
78	----do----------	Hills near Dalles, O. T
79	Infusorial mud, later	Cascade mountains, O. T.
80	Volcanic ashes	Mount Hood, O. T.
81	Silicified wood	Petaluma, California
82	----do----------	Upper Pit river, California

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CATALOGUE—Continued.

No.	Name.	Locality.
83	Silicified wood	Upper Pit river, California
84	----do	----do----do
85	Silicified wood, decayed before fossilization	----do----do
86	----do	Cascades of Columbia
87	----do	----do----do
88	----do	----do----do
89	----do	----do----do
90	Silicified wood (partially fossilized)	----do----do
91	----do----do----do	----do----do
92	----do----do----do	----do----do
93	----do----do----do	----do----do
94	Silicified wood (wholly silicified)	----do----do
95	----do----do----do	----do----do
96	----do----do----do	----do----do
97	----do----do----do	----do----do
98	----do----do----do	----do----do
99	----do----do----do	----do----do
100	----do----do----do	----do----do
101	----do----do----do	----do----do
102	----do----do----do	----do----do
103	----do	----do----do
104	----do	Shoal Water bay, W. T.
105	----do	----do----do
106	----do	----do----do
107	----do	----do----do
108	----do	----do----do
109	----do	----do----do
110	----do	----do----do
111	Lignite	----do----do
112	----do	----do----do
113	Wood unchanged, lignite beds	----do----do
114	Cone, (Abies Menziesii?)	----do----do
115	Wood of sunken forest	Columbia river
116	Wood of Abies Douglassii (recent)	
117	Wood of Abies Douglassii (fossil)	
118	Fossil plants	
119	----do	
120	Coal	Santa Clara, California
121	----do	----do----do
122	Fossil limestone overlying last	
123	Coal	Coose bay, O. T.
124	----do	----do----do
125	----do	----do----do
126	----do	Clalam bay, W. T.
127	----do	----do----do
128	----do	Cape Flattery, W. T.
129	----do	----do----do

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